International Journal on Advanced Science Engineering Information Technology

Vol.9 (2019) No. 4
ISSN: 2088-5334

The Weighting of Risk Factors for Road Infrastructure Accidents Using Analytic Hierarchy Process Method

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***Abstract*— There were 100,106 cases of traffic accidents that occurred in Indonesia in 2013, in which 26,416 people died, 28,438 people were seriously injured, and 110,448 people were mildly injured. Road infrastructure is one of the components of traffic safety. If it is not planned, designed, built and maintained properly, conditions such as poor geometry, damaged and unmaintained pavement surfaces can cause traffic accidents. Understanding of risk factors for road infrastructure accident and weighting of factors are an important step in increasing traffic safety. In addition, limited data on accidents in Indonesia also pose an obstacle in evaluating accidents. This study aims to weight risk factors for road infrastructure accident without accident data using the analytic hierarchy process (AHP) method. 40 respondents consisting of academics, practitioners, and stakeholders participated in filling out questionnaires on assessing risk factors for road infrastructure accident. The weighting results using AHP indicated that the priority ranking of accident risks from the largest to the smallest were road surface conditions, geometric conditions, road equipment, roadside hazard and road complementary buildings respectively. This study was limited to two-way, two-lane undivided urban road (4/2 UD) on straight and flat segments. Other segments and types of roads needs to be used because different types of roads have different risk factors and weights. The AHP method was used at the weighting phase without the process of assessing the existing road infrastructure.**

***Keywords*— analytic hierarchy process; risk factors for accidents; road infrastructure; weighting.**

I. INTRODUCTION

The World Health Organization (WHO) in 2015 in the global status report of road safety [1] stated that traffic accidents caused the death of more than 1.2 million people annually. Moreover, in 2012, traffic accidents were the number one cause of death in the world in the age group 15 to 29 years. In addition to fatalities, economic losses due to traffic accidents are estimated at 3% of a country's gross domestic product (GDP). WHO also wrote that 90% of accidents worldwide occurred in poor and developing countries. One of the developing countries, Indonesia also experienced problems with high traffic accidents. In 2013, there were 100,106 cases of accidents in Indonesia which resulted in 26,416 people died, 28,438 people were seriously injured, and 110,448 were mildly injured [2]. Based on the previous data, it can be concluded that traffic accidents are a problem that must be immediately addressed using appropriate preventive measures to reduce the death rate and economic losses, especially in poor and developing countries.

Traffic accidents occur as a result of the human factor, vehicle factor, or road and environmental factor as well as the interaction between these three factors. Road factor contributes 3% of accidents and increases to 34% when combined with other factors such as human factor and vehicle factor [3]. Geometric design of roads that do not comply with the standard [4]–[7], damaged road surface conditions [8], [9], dangerous roadside [10]–[12], unavailable and/or damaged street lighting [13], [14], unavailability of markers and low visibility of markers [15], [16] inappropriate signs [17], and pedestrian facilities that do not adequately function [18], [19] are some of the factors that cause traffic accidents from road infrastructure aspect.

In regard to the extent of the influence of road infrastructure on traffic accidents, this study aims to break down road infrastructure into its constituent elements (factors), weighting such factors to assess how they affect the risk of traffic accidents, and to rank such factors to assess which factors are most influential in causing an accident. This will help decision-makers to assess and handle accident-prone areas to improve road safety. Knowledge of the dangers of poor road infrastructure to traffic accidents will have implications for providing safe and comfortable road infrastructure. Well-planned, designed, built, monitored and maintained road infrastructure will increase road user safety. The factors constituting road infrastructure were weighted by using one of the expert choice methods, namely the analytic hierarchy process (AHP). The AHP method is a method that employs opinions of experts in weighting road infrastructure factors. This method is considered more appropriate with the location of the study because the accident data in Indonesia are very limited so that it will be very difficult to weight using a statistical approach. This is consistent with an argument given by Agarwal et al. [20] that comprehensive accident data is often not available. Even though it is available, it will be difficult to analyze the data because of their low quality.

Several studies on weighting the factors causing traffic accidents using the AHP method have been previously conducted by Pirdavani et al. [21], Habibian et al. [22], Najib et al. [23], Agarwal et al. [20], Kanuganti et al. [24], Sadegpour and Mohammadi [25]. The main difference between this study and those studies is elements of the risk of traffic accidents used. The determination and weighting of risk factors for road infrastructure accidents in this study were limited only to undivided two-way, two-lane roadways in urban roads (4/2 UD) in straight and flat road segments so that the derived elements of risk of the traffic accidents were based on and limited to characteristics of the type of road. The limitation was made because different types of roads had different characteristics of infrastructure and risk factors for causing accidents.

Furthermore, the discussion in this paper is divided into 3 main sections, namely: (1) methodology explaining the AHP weighting method, (2) results and discussion explaining the risk factors for road infrastructure, weighting results and ranking of these factors using the AHP method, and (3) conclusion showing the important points of the synthesis results of the entire study.

II. Material and Methods

The Analytic Hierarchy Process (AHP) was first introduced by Saaty in 1977 [26]. Figure 1 shows the flowchart of the weighting process using the AHP method. This study was divided into 3 main phases as follows.

A. Phase 1: Determination of Risk Factors for Road Infrastructure Accidents and Hierarchy Models

1) Define main and sub-factors: Road infrastructure factors deemed to be at risk of causing accidents were derived using a literature review from previous studies with similar themes. The review of such factors was studied and modified based on the objectives, focus, and limitations of this study.

2) Establish a hierarchy model: Saaty [27] explained that, in AHP, modeling a problem to be answered should be stated in the form of a hierarchical structure. The advantages that can be obtained by forming a hierarchical structure model are (a) that it is possible to understand all the variables involved and how the relationships between these variables exist, (b) problems or solutions are represented in a structured manner [28]. In AHP, once the influential factors of a problem have been determined, the hierarchical structure is formed by deriving these factors from goals, criteria, sub-criteria, and alternatives respectively [29].

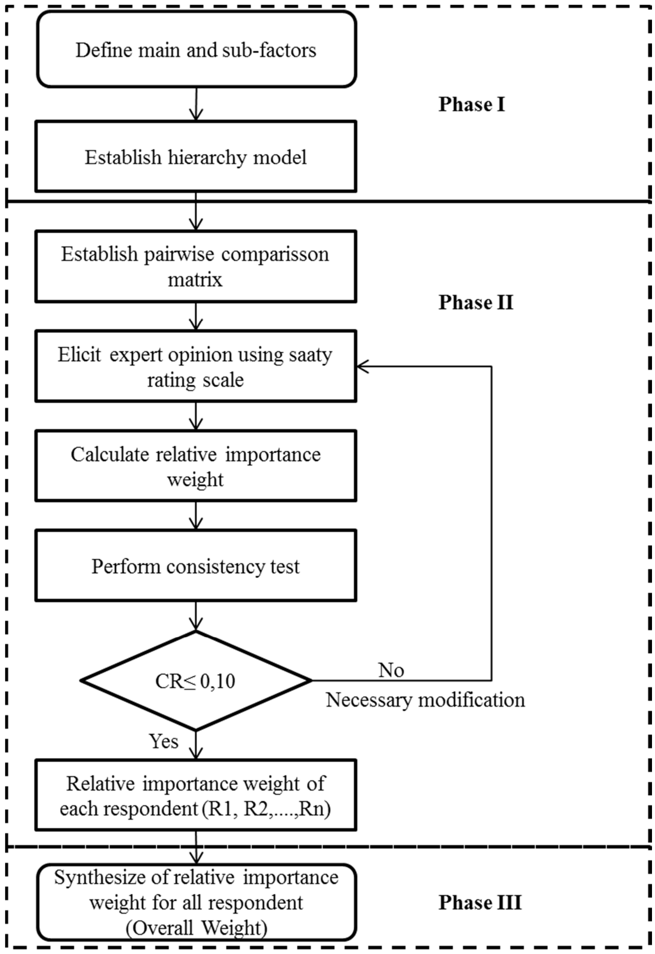

Fig. 1 Flowchart of the AHP method

B. Phase 2: Weighting of Risk Factors for Road Infrastructure Accidents

At this phase, the weighting was performed on each respondent (R1, R2, R3... R40).

1) Establish a pairwise comparison matrix: After the hierarchical structure model was completed, the next step in the AHP weighting analysis was to establish a pairwise comparison matrix. Based on the hierarchy previously formed, a pairwise comparison was applied to each element at each level. For instance, C_1, C_2...C_n were a collection of criteria/ elements, while a_{ij} represented pairwise judgments between the criteria/elements where C_i (element in line with column directional), while C_j (element in line with row), then the matrix A (nxn) can be stated as follows. It should be noted that the pairwise assessment performed by decision makers or respondents were not for all elements in the matrix above. The pairwise assessment was only performed as n (n-1) / 2 or in the upper triangle of the total number of elements in the matrix A in equation (1). The bottom of the triangle in matrix A was a relative value that showed the reciprocal value of the upper triangle where a_{ii} = 1 and aji = $1/a_{ij}$, i,j = 1,2,....,n.

$$\mathbf{A} = [\mathbf{a_{ij}}] = \begin{array}{c} \\ \mathbf{C_1} \\ \mathbf{C_2} \\ \vdots \\ \mathbf{C_n} \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} \mathbf{1} & \mathbf{a_{12}} & \cdots & \mathbf{a_{1n}} \\ \mathbf{1/a_{12}} & \mathbf{1} & \cdots & \mathbf{a_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{1/a_{1n}} & \mathbf{1/a_{2n}} & \cdots & \mathbf{1} \end{bmatrix} \end{array} \quad (1)$$

2) Elicit Expert Opinion: After the pairwise comparison matrix was completed, the next process was the process of writing the pairwise comparison matrix into a questionnaire that would be used by the decision makers/experts to assess the level of importance of the elements compared. The process of assessing the pairwise comparison by the decision makers/experts was based on which elements dominated and how much dominance they had over the comparison elements. Saaty [30] recommends using 9 rating scales as seen in Table 1.

TABLE I
RATING SCALE OF IMPORTANCE BETWEEN ELEMENTS

Intensity of importance	Definition	Explanation
1	equal importance	two categories or variables contribute equally to the objective
2	weak or slight	
3	moderate importance	experience and judgment slightly favor one category or variable over another
4	moderate plus	
5	strong importance	experience and judgment strongly favor one category or variable over another
6	strong plus	
7	very strong importance	a category or variable is favored very strongly over another; its dominance demonstrated in practice
8	very, very strong	
9	extreme importance	the evidence favoring one category or variable over another is of the highest possible order of affirmation

Respondents involved in this study were 40 people consisting of three categories of respondents, namely academics, practitioners and stakeholders. The three categories of respondents were involved in weighting the criteria for road infrastructure accidents because they had interests, knowledge, and expertise in road infrastructure safety. Academic respondents were lecturers in transportation from several universities in Indonesia, practitioner respondents were planners who were certified and experienced in road infrastructure planning, and stakeholder respondents were policy makers in 2 ministries, namely the Ministry of Public Works and the Ministry of Transportation. It was expected that the assessment given by the three groups of respondents could provide a broader and more comprehensive perspective. The number of each group of respondents in this study can be seen in Fig. 2.

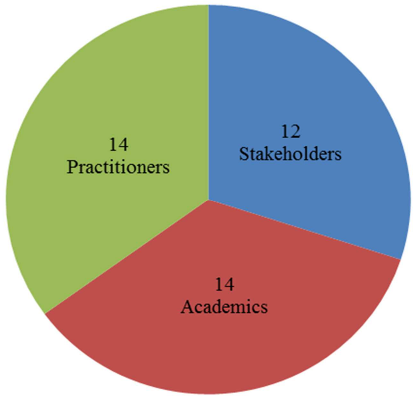

Fig. 2 Composition of respondent groups

3) Calculate relative importance weight: Calculating priority weights was the step taken after the process of assessing the pairwise comparison matrix. Several steps are taken to obtain the priority weights. Calculate the normalization matrix of matrix A. The N matrix as shown in equation (2) below was the result of normalization of matrix A after the decision makers/ experts assessed the pairwise comparison. Equation (3) shows the equation for calculating matrix N.

$$\mathbf{N} = \begin{pmatrix} \mathbf{W_{11}} & \mathbf{W_{12}} & \mathbf{W_{13}} \\ \mathbf{W_{21}} & \mathbf{W_{22}} & \mathbf{W_{23}} \\ \mathbf{W_{31}} & \mathbf{W_{32}} & \mathbf{W_{33}} \end{pmatrix} \quad (2)$$

$$\mathbf{W_{ij}} = \frac{\mathbf{a_{ij}}}{\sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{a_{ij}}} \quad (3)$$

Where $\sum_{n=1}^{n} aij$ is the number of columns of the matrix A. After the normalization matrix was completed, the next process was to determine the weight of each element. The weighting of the element in the matrix N was performed using equation (4).

$$\mathbf{W_i} = \frac{\sum_{\mathbf{j=1}}^{\mathbf{n}} \mathbf{W_{ij}}}{\mathbf{n}} \quad (4)$$

4) Perform consistency test: The consistency level of priority weights obtained from the weighting above phases was then tested first before being used at the advanced analysis phase. The assessment of the decision makers/ experts which did not meet the consistency requirements (≥ 0.1) could be used in the further analysis unless the evaluation of the decision makers/experts were corrected in the assessment process of aij. Equation (5) below was used to calculate the consistency ratio (CR), while Table 2 shows the random index (RI) value.

$$\boldsymbol{CR} = \frac{\mathbf{CI}}{\mathbf{RI}} = \frac{\textbf{Consistency Index}}{\textbf{Random Consistancy of A}} \quad (5)$$

The value of Consistency index (CI) was calculated using equation (6) and the random consistency (RI) can be seen in Table 2.

$$CR = \frac{CI}{RI} = \frac{\lambda max - n}{n-1} \quad (6)$$

Where λmax is maximum eigenvalue and n is matrix dimension.

TABLE II
RATING VALUE OF RANDOM INDEX

n	1	2	3	4	5	6	7	8	9	10
Ri	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

C. Phase 3: Synthesis of relative importance weight for all respondent

After Phase I and Phase II were completed, the assessment results from each respondent that had passed the CR test were combined into one by using the aggregation of individual priorities (AIP) method called overall weight. This total overall weight indicates the weight of risk for road infrastructure accidents.

The AHP method described in the previous section was performed for individual weighting analysis or for a decision maker (R). As a matter of fact, many decisions are not only made by one person, but involving many people/stakeholders. Analytic hierarchy process in group decision making (AHP GDM) facilitates this by using a combining technique, known as an aggregation of individual judgment (AIJ) and aggregation of individual priorities (AIP) [31]. According to Forman and Peniwati [31], AIJ is used when the group is assumed to act as a unit and the method of combining geometric mean is used to combine the assessment of a number of decision makers and AIP is used when the group is assumed as separate individuals and in AIP the technique of combining assessment from decision makers uses arithmetic mean and geometric mean methods.

This study employed the AIP method (arithmetic mean) to combine the overall assessment given by the respondents as seen in equation (7) where OW is overall relative importance weight of all respondents and w is relative importance weight of each respondent. The AIP method was employed because this study involved three different groups of respondents, namely groups of academics, groups of practitioners, and groups of stakeholders in assessing the risk of road infrastructure safety criteria.

$$\mathrm{ow} = \frac{1}{\mathrm{n}}\sum_{i=1}^{n} w1 \quad (7)$$

III. RESULT AND DISCUSSION

A. Phase I: Determination of Risk Factors for Road Infrastructure Accidents and Hierarchy Models

1) Determination of Risk Factors for Road Infrastructure Accidents: The risk factors for road infrastructure accidents were determined based on previous studies which have similar themes to this study. Table 2 shows previous studies that employed the AHP method to weight road safety factors.

TABLE III
PREVIOUS STUDIES

No	Researchers	Road Factors
1.	Pirdavani dkk., 2009 [21]	geometric conditions, traffic conditions, physical conditions, specific locations, distance from population centers
2.	Habibian dkk., 2011 [22]	straight segments, horizontal and vertical curves, bridges, tunnels, merges and intersections, side road land use
3.	Najib dkk., 2012 [23]	driving faster than limited speed, driving carelessly, adverse road and traffic conditions, obstructions, brakes defect
4.	Agarwal dkk., 2013 [20]	geometrical, surface, shoulder, drainage, street light, road marking, island condition, traffic sign and signal
5.	Kanuganti dkk., 2017 [24]	road geometric characteristics, shoulder characteristics, pavement conditions, traffic, signal and marking
6.	Sadeghpour and Mohammadi, 2018 [25]	overtaking, road alignment, road junctions, consistency, roadside

TABLE IV
RISK FACTOR FOR ROAD INFRASTRUCTURE ACCIDENTS

No	Factors	Subfactors
1	road geometry	road width
		shoulder width
		slope camber
2	road surface condition	roughness
		pavement distress
		skid resistance
3	road complementary building	sidewalk
		side drainage
		bus stop
4	road furniture	marking
		sign
		lighting
5	roadside	

The difference between those studies and this study lies in the use of road factors. This study employed factors similar to Agarwal et al. [20] and Kanuganti et al. [24] which focused on road infrastructure factors. However, this study made several modifications to meet the objectives and scope of this study. The risk factors for road infrastructure safety used in this study are shown in Table 4. Another difference is that Agarwal et al. [20] and Kanuganti et al. [24] used out-of-town road design factor as safety assessment factors, while this study used urban road design factor of 4/2 UD.

2) Hierarchy Model: The weighting analysis using the AHP method began with building a hierarchy model from the objectives to achieve. Figure 3 shows the hierarchy model of AHP on risk factors for road infrastructure accidents used in this study. The hierarchy as shown in Fig. 3 consists of 3 levels. Level 1 is the objectives and focus of this study, namely determining and weighting risk factors for road infrastructure accidents, especially on 4/2 UD urban roads 4/2 UD. Level 2 is the main risk factors for road infrastructure accidents. Level 3 is a breakdown of the main factors at level 2 into more detailed sub-factors related to the risk of accidents that could be caused by each factor at level 2. The weighting assessment using the AHP method would be performed at levels 2, 3A, 3B, 3C, and 3D to see the weight of the risk factors for road infrastructure accidents.

B. Phase 2: Weighting of Risk Factors for Road Infrastructure Accidents using AHP Method

Determination of Risk Factors for Road Infrastructure Accidents: This phase consisted of several steps, namely establish a pairwise comparison matrix, assess the pairwise comparison matrix, calculate the weight factors, and perform consistency test. The four steps produced priority weight value (wi) from each factor and sub factor at levels 2, 3A, 3B, 3C, and 3D. The priority weight value (wi) indicates the levels of risk of each factor in causing a traffic accident. The greater the value of wi, the greater the risk the factor has in causing an accident. The weighting of respondents could be used if the value of Consistency Ratio (CR) at all levels was ≤ 0.1. The number of respondents in this study was 40 respondents (R1, R2, R3, and R40). The weighting results of respondent 1 (R1) would be presented and explained as an example to represent the 40 respondents.

Table 5, Table 6, Table 7, Table 8 and Table 9 respectively show results of weighting R1 at levels 2, 3A, 3B, 3C and 3D. Table 5 shows that according to R1, road surface conditions are more at risk of causing accidents than factors of dimension, roadside, equipment, and road complements. The results of the consistency test on all levels of R1 met the requirements of Consistency Ratio (CR) of ≤ 0.1 so that the results of priority weights of R1 could be used in this study. Furthermore, the same step was performed on respondent 2 (R2) until respondent 40 (R 40).

C. Phase 3: Synthesis of Relative Importance Weight for All Respondents

The next phase was synthesizing the results of the weighting R1 to R40 at each level to produce a total weight value that would be used to see the risk of traffic accidents from road infrastructure. The AIP technique (arithmetic mean) was used to combine all the priority weights of R1 to R40. The results of the total weighting analysis, which were the synthesis of the respondents' overall priority assessment (R1 to R40) consisting of academics, practitioners, and stakeholders are shown in Table 10. The total weight values indicate the level of risk factors and sub factors for road infrastructure in causing traffic accidents. Table 10 shows the total weight of each level, both level 2 and level 3.

The weight of accident risk in the road infrastructure as shown in Table 10 can be used by the parties concerned to evaluate and identify dangerous road segments. The risk weight factor can be used as a tool to assess how much deficiency of road infrastructure in causing traffic accidents. Roads that have large deficiency factors can then be improved to increase road user safety as conducted by Pirdavani et al. [21], Habibian et al. [22], and Kanuganti et al. [24].

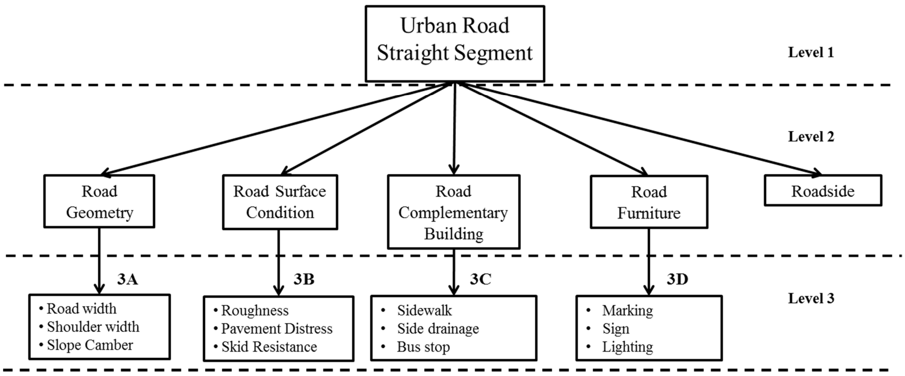

Fig. 3 Hierarchy of risk factors for road infrastructure accidents

TABLE V
WEIGHTING RESULT OF RESPONDENT 1 (R1) AT LEVEL 2

Factors	Road Geometry	Road Surface	Complementary Building	Road Furniture	Roadside	(w_i)
Road Geometry	1	1/3	3	2	1	0.207
Road Surface	3	1	3	3	2	0.391
Complementary Building	1/3	1/3	1	1	½	0.101
Road Furniture	½	1/3	1	1	1	0.125
Roadside	1	1/2	2	1	1	0.176

TABLE VI
WEIGHTING RESULT OF RESPONDENT 1 (R1) AT LEVEL 3A

Factors	Road width	Shoulder width	Slope camber	(w_i)
Road width	1	1	3	0.429
Shoulder width	1	1	3	0.429
Slope Camber	1/3	1/3	1	0.143

TABLE VII
WEIGHTING RESULT OF RESPONDENT 1 (R1) AT LEVEL 3B

Factors	Roughness	Pavement Distress	Skid resistance	(w_i)
Roughness	1	1/5	1/5	0.091
Pavement distress	5	1	1	0.455
Skid resistance	5	1	1	0.455

TABLE VIII
WEIGHTING RESULT OF RESPONDENT 1 (R1) AT LEVEL 3C

Factors	Sidewalk	Drainage	Bus stop	(w_i)
Sidewalk	1	1/5	1/5	0.091
Drainage	5	1	1	0.455
Bus stop	5	1	1	0.455

TABLE IX
WEIGHTING RESULT OF RESPONDENT 1 (R1) AT LEVEL 3D

Factors	Marking	Sign	Lighting	(w_i)
Marking	1	3	1	0.429
Sign	1/3	1	1/3	0.143
Lighting	1	3	1	0.429

TABLE X
OVERALL PRIORITY WEIGHT OF RISK FACTORS AND SUB FACTORS

No	Factors	Overall weight Level 2	Sub factors	Overall weight Level 3
1	road geometry	0.22	road width	0.51
			shoulder width	0.20
			slope camber	0.28
2	road surface condition	0.31	roughness	0.35
			pavement distress	0.33
			skid resistance	0.32
3	road complementary building	0.12	sidewalk	0.33
			side drainage	0.27
			bus stop	0.40
4	road furniture	0.20	marking	0.37
			sign	0.25
			lighting	0.38
5	roadside	0.15		

D. Phase 4: Ranking of risk factors for road infrastructure accidents

Table 11 shows the priority ranking of risks for road infrastructure accidents at level 2 and level 3. At level 2, the ranking of risk of traffic accidents from the largest to the smallest is road surface conditions, geometric conditions, road equipment, roadside hazard, and road complementary buildings.

The weight factor of the road surface conditions assessed by all respondents was high because the respondents tended to see risk factors for traffic accidents caused by conditions of skid resistance, pavement distress, and poor roughness as subfactors of road surface conditions which were more at risk of causing traffic accidents than the other four factors at level 2. The ranking of accident risk at the level 3B (road surface condition subfactor) was road roughness, pavement distress, and skid resistance. The ranking of accident risk at level 3A (road geometry subfactor) was road width, slope camber, and shoulder widt respectively.

TABLE XI
PRIORITY RANKING OF RISK FOR ROAD INFRASTRUCTURE ACCIDENTS

Level 2	Rank	Level 3	Rank
road geometry	2	road width	1
		slope camber	2
		shoulder width	3
road surface condition	1	roughness	1
		pavement distress	2
		skid resistance	3
road furniture	5	road lighting	1
		road marking	2
		road sign	3
roadside hazard	3		
road complementary building	4	bus stop with bay	1
		sidewalk	2
		side drainage	3

The ranking of accident risk at level 3D (road furniture sub factor) was lighting, marking, sign respectively. The ranking of accident risk at level 3C (road complementary building sub factor) was bus stop, sidewalk, and side drainage respectively. The results as shown in Table 10 and Table 11 do not mean that safe roads only need to be built and their surface are maintained properly and do not consider other factors such as roadside hazard or complementary road buildings. The causes of traffic accidents are very complex and traffic accidents very rarely occur due to a single factor or sub factor. Thus, a safe road from the infrastructure aspect is a road that is designed, built and maintained by prioritizing the fulfillment of engineering requirements from all factors and sub factors constituting the aforementioned road infrastructure.

IV. CONCLUSIONS

Based on the study on the determination and weighting of accident risk factors on straight and flat segments of the two-way, two-lane undivided urban roads (4/2 UD) based on the assessment of 40 respondents consisting of academics, practitioners, and stakeholders using the AHP method. Risk factors for road infrastructure accidents using the AHP method were derived in the form of hierarchy as follows, level 1 was the total weight value in road straight segment 4/2 UD, level 2 consisted of road geometry, road surface condition, road complementary buildings, road furniture, and road side, level 3A (road geometry sub factor) was roughness, pavement distress, and skid resistance, level 3B (road surface condition sub factor) was road width, shoulder width, and slope camber, level 3C (road complementary building sub factor) was sidewalk, side drainage, and bus stop, level 3D (road furniture sub factor) was marking, sign, and lighting. The ranking of the risk of traffic accidents at level 2 from the largest sequence to the smallest was road surface conditions, geometric conditions, road equipment, roadside, and road complementary buildings. The ranking of accident risk at level 3A (road geometry sub factor) was skid resistance, pavement distress, and roughness respectively. The ranking of accident risk at level 3B (road surface condition sub factor) was road width, slope camber, and shoulder width respectively. The ranking of accident risk at level 3C (road complementary building sub factor) was a bus stop, sidewalk, and side drainage respectively. The ranking of accident risk at level 3D (road furniture sub factor) was lighting, marking, sign respectively.

This study was limited to the two-way, two-lane undivided urban road (4/2 UD) on straight and flat segments. Other segments and types of roads needs to be used because different types of roads have different risk factors and weights. Also, the AHP method was only used in the weighing phase without the process of assessing the existing road infrastructure. It is expected that, in the next study, the results of weighting the factors of road infrastructure from this study can be used to evaluate and identify existing road infrastructure. The assessment of the existing road infrastructure will be useful for determining dangerous road segments.

References

[1] World Health Organization, “Global Status Report on Road Safety,” 2015.

[2] Chief of Traffic Corps Indonesian National Police, “Traffic Corps in Number 2013,” 2014.

[3] AASHTO, Policy on geometric design of highways and streets. American Association of State Highway and Transportation Officials. 2011.

[4] B. Jrew, M. Msallam, S. Khalad, and M. Abojaradeh, “Analysis and evaluation of traffic accidents for principle urban streets in arbil city in Iraq,” Diyala J. Eng. Scinces, vol. 10, no. 1, pp. 118–131, 2017.

[5] S. Mecheri, F. Rosey, and R. Lobjois, “The effects of lane width, shoulder width, and road cross-sectional reallocation on drivers’ behavioral adaptations,” Accid. Anal. Prev., vol. 104, no. December 2016, pp. 65–73, 2017.

[6] M. K. A. Ibrahim, H. Hamid, T. H. Law, and S. V. Wong, “Evaluating the effect of lane width and roadside configurations on speed, lateral position and likelihood of comfortable overtaking in exclusive motorcycle lane,” Accid. Anal. Prev., vol. 111, no. November 2017, pp. 63–70, 2018.

[7] N. Haghighi, X. C. Liu, G. Zhang, and R. J. Porter, “Impact of roadway geometric features on crash severity on rural two-lane highways,” Accid. Anal. Prev., vol. 111, no. November 2017, pp. 34–42, 2018.

[8] M. T. Sarwar and P. C. Anastasopoulos, “The effect of long term non-invasive pavement deterioration on accident injury-severity rates: A seemingly unrelated and multivariate equations approach,” Anal. Methods Accid. Res., vol. 13, pp. 1–15, 2017.

[9] S. Chen, T. U. Saeed, and S. Labi, “Impact of road-surface condition on rural highway safety: A multivariate random parameters negative binomial approach,” Anal. Methods Accid. Res., vol. 16, pp. 75–89, 2017.

[10] C. D. Fitzpatrick, S. Samuel, and M. A. Knodler, “Evaluating the effect of vegetation and clear zone width on driver behavior using a driving simulator,” Transp. Res. Part F Traffic Psychol. Behav., vol. 42, pp. 80–89, 2016.

[11] M. Jalayer and H. Zhou, “Evaluating the safety risk of roadside features for rural two-lane roads using reliability analysis,” Accid. Anal. Prev., vol. 93, pp. 101–112, 2016.

[12] M. Budzynski, K. Jamroz, L. Jelinski, and M. Antoniuk, “Why are Trees Still Such a Major Hazard to Drivers in Poland ?,” in Transportation Research Procedia, 2016, vol. 14, pp. 4150–4159.

[13] M. Uddin and N. Huynh, “Truck-involved crashes injury severity analysis for different lighting conditions on rural and urban roadways,” Accid. Anal. Prev., vol. 108, no. July 2016, pp. 44–55, 2017.

[14] S. Bozorg Chenani, M. Maksimainen, E. Tetri, I. Kosonen, and T. Luttinen, “The effects of dimmable road lighting: A comparison of measured and perceived visibility,” Transp. Res. Part F Traffic Psychol. Behav., vol. 43, pp. 141–156, 2016.

[15] K. Diamandouros and M. Gatscha, “Rainvision : The Impact of Road Markings on Driver Behaviour – Wet Night Visibility,” in Transportation Research Procedia, 2016, vol. 14, pp. 4344–4353.

[16] S. G. Charlton, N. J. Starkey, and N. Malhotra, “Using road markings as a continuous cue for speed choice,” Accid. Anal. Prev., vol. 117, no. October 2017, pp. 288–297, 2018.

[17] S. Kaplan, S. Bortei-Doku, and C. G. Prato, “The relation between the perception of safe traffic and the comprehension of road signs in conditions of ambiguous and redundant information,” Transp. Res. Part F Traffic Psychol. Behav., vol. 55, pp. 415–425, 2018.

[18] A. Osama and T. Sayed, “Evaluating the impact of connectivity, continuity, and topography of sidewalk network on pedestrian safety,” Accid. Anal. Prev., vol. 107, no. February, pp. 117–125, 2017.

[19] A. Galanis, G. Botzoris, and N. Eliou, “Pedestrian road safety in relation to urban road type and traffic flow,” Transp. Res. Procedia, vol. 24, pp. 220–227, 2017.

[20] P. K. Agarwal, P. K. Patil, and R. Mehar, “A Methodology for Ranking Road Safety Hazardous Locations Using Analytical Hierarchy Process,” Procedia - Soc. Behav. Sci., vol. 104, pp. 1030–1037, 2013.

[21] A. Pirdavani, T. Brijs, and G. Wets, “a Multiple Criteria Decision Making Approach for Prioritizing Accident Hotspots in Developing,” vol. 7671, pp. 1–17, 2009.

[22] M. Habibian, M. Mesbah, and A. Sobhani, “Ranking of hazardous road locations in two-lane two-way Rural roads with no crash record,” ATRF 2011 - 34th Australas. Transp. Res. Forum, no. September, pp. 1–11, 2011.

[23] L. Najib, I. Abdullah, L. Abdullah, and Z. Salleh, “Weight of road accident causes using analytic hierarchy process,” ARPN J. Sci. Technol., vol. 2, no. 2, 2012.

[24] S. Kanuganti, R. Agarwala, B. Dutta, P. N. Bhanegaonkar, A. P. Singh, and A. K. Sarkar, “Road safety analysis using multi criteria approach: A case study in India,” Transp. Res. Procedia, vol. 25, pp. 4653–5665, 2017.

[25] M. Sadeghpour and M. Mohammadi, “Evaluating Traffic Risk Indexes in Iran’s Rural Roads. Case Study: Ardabil-Meshkin Rural Road,” Transp. Telecommun., vol. 19, no. 2, pp. 103–112, 2018.

[26] P. Ren, Z. Xu, and H. Liao, “Intuitionistic multiplicative analytic hierarchy process in group decision making Peijia,” Comput. Ind. Eng., vol. 101, pp. 513–524, 2016.

[27] T. L. Saaty, “How to Make a Decision: The Analytic Hierarchy Process,” Interfaces (Providence)., vol. 24, no. 6, pp. 19–43, 1994.

[28] M. Bertolini, M. Braglia, and G. Carmignani, “Application of the AHP methodology in making a proposal for a public work contract,” Int. J. Proj. Manag., vol. 24, no. 5, pp. 422–430, 2006.

[29] T. L. Saaty, “How to make a decision: The Analytic Hirarchy Process,” Eur. J. Oper. Res., vol. 48, no. 1, pp. 9–26, 1990.

[30] T. L. Saaty, “Axiomatic Foundation of the Analytic Hierarchy Process,” Manage. Sci., vol. 32, no. 7, pp. 841–855, 1986.

[31] K. Forman, E. Peniwati, “Aggregating Individual Judgements and Priorities with the Analytic Hierarchy Process,” *Eur. J. Oper. Res.*, vol. 108, pp. 165–169, 1998.