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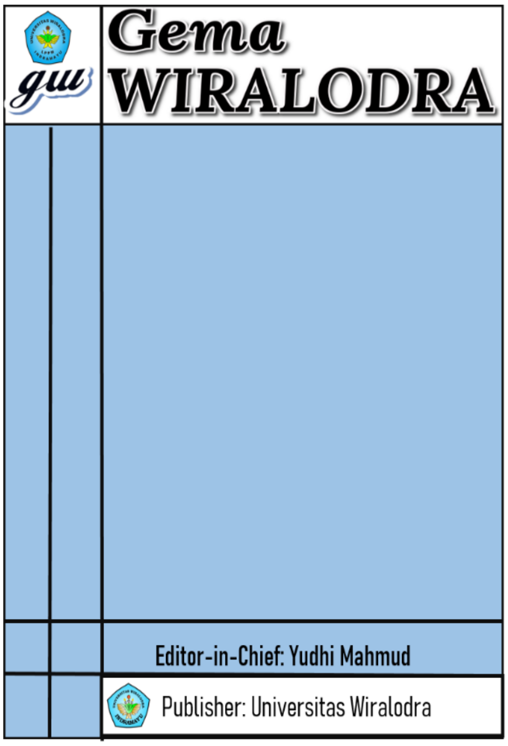

Equivalent Accident Number (EAN) and Upper Control Limit (UCL) Relationship to Multi-criteria Model Analyzed by Idalin et al. on Several National Roads

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Original Article

Equivalent Accident Number (EAN) and Upper Control Limit (UCL) Relationship to Multi-criteria Model Analyzed by Idalin et al. on Several National Roads

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Abstract
In Indonesia, to determine whether a road section is a crash-prone location (LRK), accident data from the local police is required, meaning that an accident needs to occur first. The Idalin et al (2018) method is a road safety audit (AKJ) method with a multi-criteria analysis model to calculate the probability (%) without using accident data, so that it can predict accidents based on 24 road geometric parameters and traffic characteristics. The purpose of the study was to determine the correlation of the Equivalent Accident Number (EAN) and Upper Control Limit (UCL) values to the Idalin et al (2018) Method. The flow of this study is conduct surveys and collect primary and secondary data on 4 national roads with different characteristics, conduct accident prone location (LRK) scoring, carrying out statistical tests between probability values and EAN values. The implication of the results of this study is that everyone can predict accidents based on existing road conditions. The results of the study are that the greater the probability value, the greater the EAN and UCL values with a high positive correlation (r2> 0.82), and the weight of urban road accidents is influenced by traffic attributes (26-43%) and inter-city roads are influenced by cross-sectional conditions (23-28%).
Keywords: Road Safety Audit (AKJ), Equivalent Accident Number (EAN), National Roads, Accident-Prone Location (LRK), Multi Criteria Analysis, Accident Prediction, Probability, Upper Control Limit (UCL)

1. Introduction

One of the most important ways to reduce the high rate of traffic accidents is to create an accident prediction method that is easy to use. The big problem in Indonesia, to find out whether a road section is an accident-prone location (LRK) need accident data from the local police, meaning an accident needs to occur first.

The Idalin et al (2018) method is a road safety audit method (AKJ) with a multi-criteria analysis model created to calculate probability (%) without using accident data based on a total of 24 parameter from road geometric parameters and traffic characteristics that refer to regulations/guidelines before 2018. Probability is the likelihood of something happening, expressed as a number from 0% (minimum) to 100% (maximum). The method of Idalin et al (2018) is very important to predict the occurrence of accidents but has not been practiced on any road section and there is no mention of the guidelines used and some advantages and disadvantages were found.

24 Parameter from Idalin et al (2018) method need to be refined by developing methods, considering that in the last 5 (five) years, the Indonesian Government has updated the highest regulation, namely the Law relating to traffic safety on road infrastructure, in accordance with the mandate of the 1945 Constitution of the Republic of Indonesia Article 33 paragraph (4) states that road infrastructure is the basic infrastructure in the public service of the national transportation system in order to achieve connectivity between centers of activity, balance and equitable development between regions, improving the central and regional economies in the national economic unity.

The solution offered in this research is to check the renewal of guidelines/regulations after 2018 which will certainly affect the value of each parameter. Law No. 6 of 2023

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concerning Job Creation Article 222 (1) states that the Central Government is obliged to develop industry and infrastructure technology that ensures security, safety, order, and smoothness of traffic and road transportation. Then it is also mentioned in Law No. 2 of 2022 concerning Roads Article 2 states that the implementation of roads is carried out based on the principle of safety.

2. Method

Stages of the Analysis Process

A brief explanation of the flow diagram in the following research is as follows:
Look for references from national and international journals; Determining *research gaps* ; Finding the Idalin et al (2018) Method; Identifying problems; Determining research objectives; Determine the research location; Conduct surveys and collect primary and secondary data; Conduct accident prone location (LRK) scoring; Carrying out statistical tests between probability values and EAN values;

Research sites

The Idalin et al (2018) method is intended for inter-city roads only . In the context of evaluation, it is necessary to use other characteristics for future development stages. The research location will be carried out on 4 roads with different characteristics for each based on the following source https://sigi.pu.id/portalpupr/home :

- Jalan Raya Sultan Agung, Bekasi City (3.5 km) = National road status, Urban area type, primary arterial function, Class I, Flat road terrain slope (<10%);
- Tajur Highway, Bogor City (5.1 km) = National road section status, Urban area type, Primary arterial function, Class II, Hill road terrain slope (10-25%);
- Puncak Highway (15 km) = National road section status, Urban area type, Primary collector function, Class III, Hill road terrain slope (10-25%);
- Puncak Highway (7 km) = National road section status, Inter-city area type, Primary collector function, Class III, Mountain road terrain slope (>25%).

Multi Criteria Analysis Model

Table 1 below is a table that can be filled in and selected based on existing conditions. Each *surveyor* certainly has a different perspective based on the results of visual observations during field surveys. There is some data that needs to be processed to determine the score obtained in the form of deficiencies which can be calculated using Formula 1 below.

$$Defisiensi = \left(\frac{(Standar\ yang\ berlaku) - (Kondisi\ Eksisting)}{(Standar\ yang\ berlaku)}\right) x\ 100\% \qquad (1)$$

Table 1
Multi Criteria Analysis Method (Idalin et al, 2018)

No.	Parameter	Scoring				
		1 (min value)	2	3	4	5 (max value)
1	Lane Width (	>3.5 m	3.3 – 3.5 m	3 – 3.3 m	2.7 – 3 m	< 2.7m
2	Corner Width (m)	$L_{ex} > L_{hit}$	Deficiency = 0 – 25%	Deficiency =25–50%	Deficiency = 50-75%	Deficiency = 75-100%
3	Shoulder Width (m)	>2m	Deficiency = 0 – 25%	Deficiency =25–50%	Deficiency = 50-75%	Deficiency = 75-100%
4	Shoulder Type	Hardened	Gravel/Sirtu	Partially Hardened	Grass	Land
5	Stopping Visibility (m)	$JPH_{ex} > 1.2x\ JPH_{std}$	Deficiency = 0 – 25%	Deficiency =25–50%	Deficiency = 50-75%	Deficiency = 75-100%
6	Leading Viewing Distance (m)	$JPM_{ex} > 1.2x\ JPM_{std}$	Deficiency = 0 – 25%	Deficiency =25–50%	Deficiency = 50-75%	Deficiency = 75-100%

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No.	Parameter	Scoring				
		1 (min value)	2	3	4	5 (max value)
7	Radius (m)	$R_{ex} > 1.2x R_{std}$	Deficiency = 0 – 25%	Deficiency =25–50%	Deficiency = 50-75%	Deficiency = 75-100%
8	Superelevation (%)	8-10% or 10-12%	6-8% or 12-14%	4-6% or 14-16%	2-4% or 16-18%	<2% or>18%
9	Tangent length between 2 bends (m)	$>1.2 \text{ x } T_{std}$	Deficiency = 0 – 25%	Deficiency =25–50%	Deficiency = 50-75%	Deficiency = 75-100%
10	Transition Curve	Yes, according to standards	-	There are deficiencies	-	There isn't any
11	R No. Between 2 Adjacent Bends	>0.8	0.6-0.8	0.4-0.6	0.2-0.4	<0.2
12	Flatness (%)	0-2.5%	2.5-5%	5-7.5%	7.5-10%	>10%
13	Critical Ramp Length (m)	$P_{ex} < P_{critical}$	Deficiency = 0 – 25%	Deficiency =25–50%	Deficiency = 50-75%	Deficiency = 75-100%
14	Maximum Tangent Length (m)	$T_{ex} < T_{max}$	Deficiency = 0 – 25%	Deficiency =25–50%	Deficiency = 50-75%	Deficiency = 75-100%
15	Side Slopes	Flatter than 1:5	1:4 to 1:5	1:3 to 1:4	1:2 to 1:3	Steeper than 1:2
16	Clear Zone (m)	$C_{ex} < C_{std}$	Deficiency = 0 – 25%	Deficiency =25–50%	Deficiency = 50-75%	Deficiency = 75-100%
17	Hazard Type	There are No. obstacles, cliffs or ravines	Poles/Trees etc. < 20/km without cliffs/ravines	Poles/trees, etc. numbering > 20 pieces/km or guardrails, fences	Cliffs/retaining walls/houses/open channels slope > 1:3 and >0.5 m deep	Ravine/water channel with a depth of > 2.5 m without guardrail
18	Street Lighting	Enough	-	Not enough	-	There isn't any
19	Signs and Markings	Complete	Maximum 4 types of signs/markings	Maximum 3 types of signs/markings	Maximum 2 types of signs/markings	Maximum 1 type of sign/marking
20	Number of Driveways (number/km)	<5	6-10	11-15	16-20	>20
21	Proportion of Heavy Vehicle Volume (%)	< 5%	5-10%	10-15%	15-20%	>20%
22	Number of Pedestrians (person/day)	0-50	50-100	100-150	150-200	>200
23	Special Alignment Conditions	There isn't any	-	There is 1	-	> 1
24	Difference between Operational Speed (V85) and Speed Limit	$V_{85} < V_{limits}$	$V_{85} - V_{limit} = 0 – 10$	$V_{85} - V_{limit} = 10 – 20$	$V_{85} - V_{limit} = 20 – 30$	$V_{85} - V_{limit} = 30 – 40$

Accident Probability

After all parameters have been filled in by *the surveyor* , the probability of an accident on that road section can be calculated using Formula 2 below and produces probability information which can be seen in Table 2 below .

$$Probabilitas = \left(\frac{Total\ skor - Skor\ Minimal}{Skor\ Maksimal - Skor\ Minimal}\right) x\ 100\% \quad (2)$$

Total Score = Total number of measurement results scores at location ;
Maximum Score = The highest possible score in the condition that all parameters have a score of 5, namely = 5 x 24 = 120 ;
Minimum Score = The lowest possible score in the condition that all parameters have a score of 1, namely = 1 x 24 = 24 ;

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Table 2
Probability Information

No	Probability	Information
1	0%	Very small
2	0% - 25%	Small
3	25% - 50%	Currently
4	50% - 75%	Big
5	>75%	Very large

Based on Table 2 above , it can be concluded that the greater the probability, the greater the probability of an accident occurring on a road section (Idalin et al, 2018).

Equivalent Accident Number (EAN) Models

According to Susilo et al (2019), not all roads in an area are categorized as accident-prone locations (LRK). LRK ranking is carried out to determine the worst LRKs that need to receive priority treatment first. The EAN (*Equivalent Accident Number*) method uses a numerical economic scale to weigh the level of accidents based on the severity of the victims. The method used to generate the EAN value is by processing accident data that has been obtained from the local police with calculations using Formula 3 below.

$$EAN = (\Sigma MD \times EAN\ MD) + (\Sigma LB \times EAN\ LB) + (\Sigma LR \times EAN\ LR) + (\Sigma KM \times EAN\ KM) \quad (3)$$

EAN = Equivalent Accident Number ;
AEK = Accident Equivalent Number ;
MD = Death Victims ;
LB = Seriously Injured Victim ;
LR = Lightly Injured Victims ;
KM = Material Loss .

The equivalent figures used are the latest equivalent figures from Susilo (2013) based on the results of the *Focus Group Discussion agreement* , namely Deaths at 100, Serious Injuries at 20, Light Injuries at 5 and Material Losses at 1.

Upper Control Limit (UCL) Models

The method used to Priority Determination of Accident Prone Locations using the UCL Method (*Upper Control Limit*) that has been obtained from the local police. Road segments with accident rates above the UCL line are defined as accident-prone locations using Formula 4 below.

$$\lambda + 2.576 * \sqrt{((\lambda/(m) + (0.829/m) + (½ * m))} \quad (4)$$

UCL = upper limit control line ;
λ = average accident rate in units accidents per *exposure ;*
m = *exposure unit*, EAN value.

Simple Linear Regression Test

Aims to test the influence of one independent variable on the dependent variable. To measure how well the regression model fits a serial data *sample*, it is necessary to calculate the coefficient of determination which is symbolized by the symbol r^2 which can be seen in Table 3 below .

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Table 3
Coefficient of Determination

r^2	Interpretation
0	Not Correlated
0.01-0.2	Very low
0.21-0.4	Low
0.41-0.6	Somewhat Low
0.61-0.8	Enough
0.81-0.99	Tall
1	Very high

Data Retrieval - Cross Section Condition
Consisting of Lane Width (m), Corner Width (m), Shoulder Width (m), Shoulder Type, Side Slope, Clear Zone whose data can be retrieved by:
- Download the *GPS Tracker application*;
- Select a starting point, then click start;
- Search to the final point, using foot or vehicle, then click finish.

Data Retrieval - Visibility
Consisting of Stopping Sight Distance (m), Leading Sight Distance (m). Here are some steps to measure overtaking visibility whose data can be retrieved by:
- Prepare the equipment necessary for the survey, such as a long ruler or accurate distance measurer, a stopwatch or timing device, and a recording device or notebook;
- Determine the start and end points of the survey where the vehicle approaches the vehicle to be overtaken, ensuring that it can be clearly seen by the driver; Set the speed of the vehicle to be used in the survey, for example, 60 km/h;
- Start the journey from the survey starting point at the specified speed; Note the time spent to reach the survey endpoint

Here are some steps to measure stopping sight distance:
- Choose a reference point that is clearly visible and easy to recognize;
- Set the observer's position; Begin to notice the selected object or sign as a reference point while moving forward in a focused manner;
- When objects or signs begin to no longer be clearly visible, mark a position on the road as a stopping point;
- Use a distance measuring device such as a ruler, measuring wheel, or other measuring device to measure the distance between the starting point and stopping point.

Data Retrieval - Vertical Alignment
Consisting of Radius (m), Superelevation (%), Tangent Length between 2 bends (m), Transition Curve, R Ratio Between 2 Adjacent Bends Slope (%), Critical Ramp Length (m), Maximum Tangent Length (m) . To calculate and measure slope, several tools and appropriate formulas are required. Here are some steps can follow:
- Some commonly used tools are *a spirit level* or *digital inclinometer* ;
- Place the measuring tool on the surface where the slope will be measured. Make sure the tool is placed stably and does not move;

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- If using *a spirit level* , make sure the air bubble in *the spirit level* is in the middle, which indicates a flat surface. If using *a digital inclinometer* , follow the instructions for use on the device;
- Read and record the slope measurement results. If using *a spirit level* , read the slope of the scale on the tool. If using *a digital inclinometer* , the device will provide direct readings on the screen;

Data Retrieval - Traffic Attributes

Consists of Hazard Type, Road Lighting, Signs and Markings, Number of Driveways (number/km), Proportion of Number of Heavy Vehicles (%), Number of Pedestrians (people/day), V85 Difference and Speed Limit. Here are several steps to measure/record traffic attributes:

- Equipment preparation and identify start and end points;
- Determine the measurement path and determine the start and end points of the measurement;
- Take measurements and record the measurement results;
- Data analysis, the minimum speed limit for vehicles on arterial/national roads is 70 km/hour. Then it is necessary to obtain visual observation speed data from each passing vehicle.

3. Results and Discussion

The Government's Role in Traffic Accidents

The government is responsible for preventing road users from experiencing accidents, so it is obliged to ensure the creation of traffic and road transportation safety (Susilo et al, 2018). Renewing and reviewing basic laws and regulations regarding traffic can reduce the occurrence of traffic accidents (Wang et al, 2019). So, it is necessary to carry out safety audits of road infrastructure in accident-prone locations or other developments in the field of safety (Pradana et al, 2020)

National General Plan for Road Safety (RUNK) 2021-2040

In line with updating regulations, the Indonesian Government issued Presidential Regulation Number 1 of 2022 concerning the National General Plan for Road Traffic and Transportation Safety for 2021-2040. The RUNK development concept uses a 5 pillar approach, namely a safe system (Bappenas); Safe roads (Ministry of PUPR); Safe Vehicles (Ministry of Transportation); Safe road users (Police); Handling Accident Victims (Ministry of Health). This research focuses more on the 2nd Pillar regarding safe roads.

Road Safety Audit Process

According to Bina Marga (2023), a road safety audit (AKJ) is a formal test of the potential for traffic conflicts and traffic accidents from a new road design for which there is no/no accident data to ensure a high level of safety for the new road from the first day it is operated. Road Safety Inspection (IKJ) is a road safety audit activity for operational/existing roads which aims to identify characteristics that can develop over time as a safety problem. Investigation of Accident-Prone Locations (LRK) is a search activity at locations with a high number of accidents with repeated accidents in a relatively similar space and time span resulting from a certain cause.

Probability Prediction Based on Road Geometric and Traffic Characteristics

There are 2 main parameters, namely Road Geometric Conditions and Traffic Characteristics, each parameter consisting of several indicators with a total of 24 indicators. The assessment is carried out using a Multi Criteria Analysis system with a value scale of 1

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(minimum) to 5 (maximum) where each option can be selected based on the expertise of the surveyors which can be seen in **Table 1** above. In the initial research, this method was intended for inter-city roads, because on these roads there was minimal accident data from the local police.

Road Geometric

Regarding the Road Geometric Condition Parameters, the source and year of the regulations/guidelines used to create the Idhalin et al (2018) method are not included, considering that the research was conducted in 2018, the limitation of this research is that the author assumes that the Idhalin et al (2018) method uses regulatory sources/ guidelines are below 2018, while if the latest regulations/guidelines are found to be above 2018 then they are not used or used as suggestions for future research. In the Idalin et al (2018) method, the 17 parameters are also not grouped based on type. Therefore, the author made a grouping, namely Cross Section Condition = Lane Width (m), Bend Lane Width (m), Shoulder Width (m), Shoulder Type, Side Slope, Clear Zone; Viewing Distance = Stopping Viewing Distance (m), Leading Viewing Distance (m); Horizontal Alignment = Radius (m), Superelevation (%), Tangent length between 2 bends (m), Transition Curvature, R Ratio Between 2 Adjacent Bends; Vertical Alignment = Slope (%), Critical Slope Length (m), Maximum Tangent Length (m); Special Alignment Conditions = A combination of sharp bends plus descents or inclines, bends between long tangents, and combined bends in the same direction.

Theory of Road Geometric Linkage to Traffic Accidents

The more curves the road has, the higher the chance of an accident occurring, 86% (Chen et al, 2021). The size of the curve radius on the road alignment greatly influences the frequency of accidents (Wu et al, 2020). The causes of accidents include the large number of visual obstructions (Kurniati et al, 2021). It is necessary to carry out routine monitoring of road conditions, especially of road shoulders and sidewalks which tend to change function (Pradana et al, 2020).

Traffic Characteristics

Regarding Traffic Characteristic Parameters, the source and year of the regulations/guidelines used to create the method are not included, considering that the research was conducted in 2018, the limitation of this research is that the author assumes that the Idhalin et al (2018) method uses a source of regulations/guidelines from 2018. in calculating 7 indicators, namely: Hazard Type, Road Lighting, Signs and Markings, Number of Driveways (number/km), Proportion of Number of Heavy Vehicles (%), Number of Pedestrians (people/day), V85 Difference and Speed Limit.

Theory of the Relationship between Traffic Characteristics and Accidents

Increasing vehicle speed can have an effect on accident rates (Wang et al, 2022). Motorbikes on major roads will be in safe condition if the vehicle speed does not exceed 65.8 km/hour (Susanto et al, 2020). Accidents will occur 13.50 times higher for drivers who violate the speed limit compared to drivers who do not exceed the speed limit (Luthfiyani et al, 2021). Installation of traffic signs must be carried out in accident-prone areas to ensure safe roads (Jun et al, 2020). Placing signs in appropriate places can reduce the percentage of accident victims by around 5 - 10%, even warning signs at road corners can reduce accident victims by up to 35% (Mardiana, 2020). 46% of accidents occur when the number of vehicles passing on a road is 16,000 – 25,000 vehicles/day (Wu et al, 2022).

Normative Reference

The regulations used in the Idalin et al (2018) method use regulations before 2018. Meanwhile, in the last 5 years (2018-2023), there have been many changes to regulations relating to Geometric and Traffic Characteristics which are ordered from the highest (Law - Invite) to the lowest (Guidelines), namely:

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Law 2/2022 concerning Roads replaces Law 38/2004 concerning Roads; Law 6/2023 concerning Job Creation, replacing Law 22/2009 concerning Road Transport Traffic; PUPR Ministerial Regulation 4/2023 Guidelines for Road Functionality as a replacement for PUPR Ministerial Regulation 11/2010 concerning Procedures and Requirements for Road Functionality; PUPR Ministerial Regulation 5/2023 concerning Road Planning and Technical Requirements replacing PUPR Ministerial Regulation 19/2011 concerning Road Technical Planning Requirements and Criteria; Minister of Transportation Regulation 13/2014 concerning Road Signs; Minister of Transportation Regulation 67/2018 concerning Road Markings replacing Minister of Transportation Regulation 34/2014 concerning Road Markings; Minister of Transportation Regulation Number 14 of 2021 concerning Road Control and Safety Equipment replacing Minister of Transportation Regulation Number 82 of 2018 concerning Road Safety Equipment; SNI 7391:2008 Specifications for Street Lighting in Urban Areas; 2021 Road Geometric Design Guidelines (PDGJ) Replacement of the 1997 Bina Marga Inter-City Road Design Guidelines and 2004 Bina Marga Urban Road Design Guidelines; Indonesian Bina Marga Road Capacity Guidelines 2023 Replacement for Indonesian Road Capacity Manual; Technical Instructions for Road Worthiness Test for the 2023 Bina Marga Star Rating System as a replacement for the 2014 Instructions for Implementing the Functionality of Bina Marga Roads. So, it is necessary to develop methods based on the latest parameters above 2018, which influence the number and changes in parameter values.

Types of Road Section Characteristics Based on PUPR Ministerial Regulation Numbers 4 and 5 of 2023

The Idalin et al. (2018) method is intended for national roads with inter-city areas using normative references before 2018. In the evaluation context, this method needs to be used on national roads with other characteristics based on the latest regulations above 2018. Based on Ministerial Regulations PUPR 4/2023 concerning Guidelines for Road Functionality, road sections are divided into 2, namely:

- Status = National, namely arterial roads and collector roads in the primary road network system connecting provincial capitals and national strategic roads;
- Area Type = Urban, built-up area at least 400 m along the road. Inner-cities, areas outside cities/small towns/rural areas, built-up areas on the side of the road that do not impact the road, or roads separated by guardrails or walls.

Based on PUPR Ministerial Regulation 5/2023 concerning Road Planning and Technical Requirements, road sections are divided into 3, namely:

- Function = Primary Artery , minimum design speed 60 km/hour; Primary Collector, minimum design speed 40 km/hour;
- Class = I is arterial and collector roads that can be passed by motorized vehicles with a length not exceeding 18 m. II, arterial, collector, local and environmental roads that can be passed by motorized vehicles with a length not exceeding 12 m. III, arterial, collector, local, and environmental roads that can be passed by motorized vehicles with a length not exceeding 9 m;
- Road Terrain Slope = Flat (<10%), Hill (10-25%), Mountain (>25%).

Recapitulation of Parameters and Normative References Based on Numbers

The results show that the Idalin et al. 2018 method does not group parameters and does not explain the normative references used. So the author made a descriptive analysis based on literature studies which can be seen in detailed parameters using 24 parameters and 14 normative references which can be seen in Figure 1 and Figure 2 below.

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Figure 1.
Percentage of Parameter Grouping Based on Number

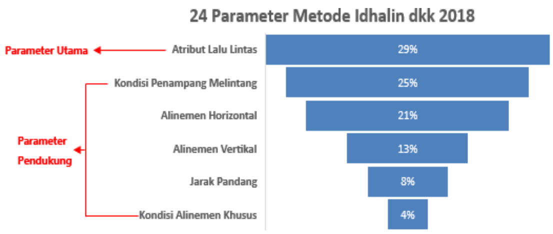
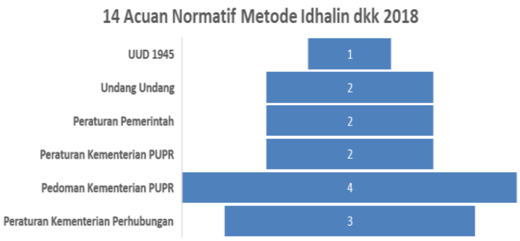


Figure 2
Grouping of Normative References Based on Number



The highest percentage of inter-city road accident parameters, according to Idalin et al (2018) is the Traffic Attribute Group of 29% or or as many as 7 parameters (Type of Hazard, Road Lighting, Signs and Markings, Number of Driveways, Proportion of Number of Heavy Roads, Number of Pedestrians, Speed Difference) which can be set as the main parameter, while the remaining 17 parameters can be said to be supporting parameters. Then the highest percentage of normative references is the Ministry of PUPR's guidelines, which are 4. After knowing the main parameters, continue to find out the weight of the accident parameters on each road section, which is explained in the next sub-chapter.

Detailed Calculation of Probability Values and Accident Weightings on One Road Section

Data on 24 parameters was obtained after a visual observation survey on each section which was then filled in on the form that had been created. One of the calculations is the Jalan Raya Puncak KM 83-85 section with characteristics of national status, inter-city area type, primary collector function, class III and mountain road terrain slope (>25%) with a reference image of existing conditions which can be seen in Figure 3 below.

Figure 3
Reference Image of Puncak Highway Section KM 83-85 (Inter-City)

The overall calculation can be seen in **Table 4** below, which is the result of the author's modification of what was previously seen in **Table 1** belonging to Idalin et al (2018).

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Table 4
Calculation Results of the Multi Criteria Model Analysis of the Puncak Highway Section KM 83-85 (Inter-City)

No.	Parameter	Applicable Standards (a)	Existing Results (b)	Deficiency ((a)-(b))/(a))* 100	Existing Score	Total Accumulation (c)	Weight % (c)/(e)	Number of Parameters (d)	Min Score (1)*(d)	Max Score (5)*(d)
A1				**Cross Section Condition**						
A.1.1	Lane Width (m)	3.75	-	-	2	10	23	6	6	30
A.1.2	Corner Width (m)	0.8	1.5	(b) > (a)	1					
A.1.3	Shoulder Width (m)	2.5	1	60	4					
A.1.4	Shoulder Type	Hardened	-	-	1					
A.1.5	Side Slopes	>2 %	-	-	1					
A.1.6	Clear Zone (m)	4	4.5	(b) > (a)	1					
A2				**Visibility**						
A.2.1	Stopping Visibility (m)	120	200	(b)>1.2*(a)	1	2	4	2	2	10
A.2.2	Leading Viewing Distance (m)	550	650	(b)>1.2*(a)	1					
A3				**Horizontal Alignment**						
A.3.1	Radius (m)	210	37	82	5	9	21	5	5	25
A.3.2	Superelevation (%)	max 10%	-	-	1					
A.3.3	Tangent length between 2 bends (m)	20	40	(b)>1.2*(a)	1					
A.3.4	Transition Curve	60	65	-	1					
A.3.5	R Ratio Between 2 Adjacent Bends	R1>R2	-	-	1					
A4				**Vertical Alignment**						
A.4.1	Flatness (%)	5	-	-	5	7	16	3	3	15
A.4.2	Critical Ramp Length (m)	460	500	(b)>1.2*(a)	1					
A.4.3	Maximum Tangent Length (m)	80	100	(b)>1.2*(a)	1					
A5				**Special Alignment Conditions**						
A.5.1	Special Alignment Conditions	-	-	-	5	5	11	1	1	5
A6				**Traffic Attributes**						
A.6.1	Hazard Type	-	-	-	3	10	23	7	7	35
A.6.2	Street Lighting	-	-	-	1					
A.6.3	Signs and Markings	-	-	-	2					
A.6.4	Number of Driveways (number/km)	-	-	-	1					
A.6.5	Proportion of Number of Heavy Cargos (%)	-	-	-	1					
A.6.6	Number of Pedestrians (person/day)	-	-	-	1					
A.6.7	The difference between V85 and Speed Limit	-	-	-	1					
					Total	**43 (e)**	**100**	**24**	**24**	**120**

One example of using a multi-criteria analysis model is in parameter A.6.5 the proportion of heavy vehicles which is located in Table 4 above. Based on the results of visual observations and the author's calculations, the proportion of heavy vehicles obtained a result of 2%. Based from Table 2 above, it can be categorized into score 1 (minimum). It can be concluded that on this road section, there is a small possibility of an accident (score 1) based on the proportion of heavy vehicles. This also applies to other parameters which refer to the results of visual observation surveys and measurements.

Of the total 24 parameters, there are some parameters that use deficiency standards (the difference between standard values and existing conditions) to determine the multi-criteria analysis score. One example is parameter A.3.1 radius (m) which is located in Table 4 above. The following are the results of visual observations and the author's calculations, radius deficiency results in 82% using Formula 1 above.

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$$\text{Defisiensi} = \left(\frac{(\text{Standar yang berlaku}) - (\text{Kondisi Eksisting})}{(\text{Standar yang berlaku})}\right) \text{x } 100\%$$

$$Defisiensi = \left(\frac{(210) - (37)}{(210)}\right) x\ 100\%$$

$$Defisiensi = 82\ \%$$

Based from Table 2 above, a score of 82% can be categorized into a score of 5 (maximum). It can be concluded that on this road section, there is a high probability of an accident (score 5) based on the radius (m). This also applies to other parameters which refer to the results of visual observation surveys along with standard deficiency measurements. Recapitulation calculations can be carried out after all 24 parameters are filled in. The following is one of the probability prediction results on the Tajur Highway KM 83-85 section, which is 20% using Formula 2 above.

$$Probabilitas = \left(\frac{Total\ skor - Skor\ Minimal}{Skor\ Maksimal - Skor\ Minimal}\right) x\ 100\%$$

$$Probabilitas = \left(\frac{43 - 24}{120 - 24}\right) x\ 100\%$$

$$Probabilitas = 20\%$$

Based from Table 1 above, the value of 20% can be categorized as small. For complete calculation results on Jalan Raya Puncak KM 83-85 (Inter-City) can be seen in Table 4 below. The weighting refers to the results of the main parameters in Figure 1 above, where each road segment characteristic has different results. One of the calculations in Table 4 above is that the weight of accidents in the cross-sectional parameter group is 23% which is obtained from a simple division calculation:

Weight = (Total accumulation per parameter) / (Total accumulation throughout parameters) * 100 = (10 / 23) * 100 = 23 %

Detailed Calculation of EAN and UCL Values on One Road Section

To determine accident-prone locations, accident data is needed from the Police at each research location in the last 5 years (2018-2023), then processed using the EAN method to determine the highest results, so it can be said to be an accident-prone location with a large coefficient belonging to Susilo et al (2019) of 100 for Death (MD), 20 for Serious Injuries (LB) and 5 for Light Injuries (LR). Then the EAN value can be processed again using the UCL method to determine the maximum accident limit value on a road section.

The following is one of the calculations, namely on the 5.1 km long Tajur Highway section with characteristics of national status, urban area type, primary arterial function, class II and hilly road terrain slope (10-25%) using **Formula 3** and **Formula 4** in on .

$$\begin{aligned} EAN &= (\Sigma MD \times EAN\ MD) + (\Sigma LB \times EAN\ LB) + (\Sigma LR \times EAN\ LR) \\ &\quad + (\Sigma KM \times EAN\ KM) \\ &= (12\ x\ 100) + (1\ x\ 20) + (0\ x\ 5) + (0\ x 1) = 1220 \end{aligned}$$

$$\begin{aligned} UCL &= \lambda + 2.576 * \sqrt{}((\lambda/(m) + (0.829/m) + (½ * m)) \\ &= 738 + 2.576 * \sqrt{}((738/(1220) + (0.829/1220) + (1/2 * 1220)) = 802 \end{aligned}$$

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This road segment has a higher EAN value of 1220 compared to the UCL value of 802, so that this road segment is included in the priority for handling accident-prone locations. All recapitulation shown in **Table 5** below.

Table 5

Calculation of EAN and UCL Values (2018-2023) for the Tajur Highway Section

KM	2018						2019						2020					
	MD	EAN	LB	EAN	L.R	EAN	MD	EAN	LB	EAN	L.R	EAN	MD	EAN	LB	EAN	L.R	EAN
4-5	1	100	-	0	1	5	-	0	-	0	-	0	-	0	-	0	2	10
3-4	1	100	-	0	2	10	-	0	-	0	1	5	1	100	-	0	2	10
2-3	1	100	-	0	4	20	-	0	-	0	1	5	1	100	-	0	-	0
1-2	2	200	1	20	-	0	1	100	-	0	-	0	2	200	1	20	-	0
0-1	3	300	1	20	-	0	1	100	-	0	-	0	2	200	-	0	-	0
KM	2021						2022						2023					
	MD	EAN	LB	EAN	L.R	EAN	MD	EAN	LB	EAN	L.R	EAN	MD	EAN	LB	EAN	L.R	EAN
4-5	-	0	-	0	4	20	-	0	-	0	5	25	-	0	5	100	2	10
3-4	1	100	1	20	3	15	1	100	1	20	4	20	-	0	1	20	1	5
2-3	1	100	-	0	1	5	1	100	1	20	-	0	1	100	1	20	1	5
1-2	2	200	-	0	5	25	2	200	1	20	-	0	1	100	-	0	3	15
0-1	-	0	-	0	-	0	3	300	-	0	-	0	3	300	-	0	-	0

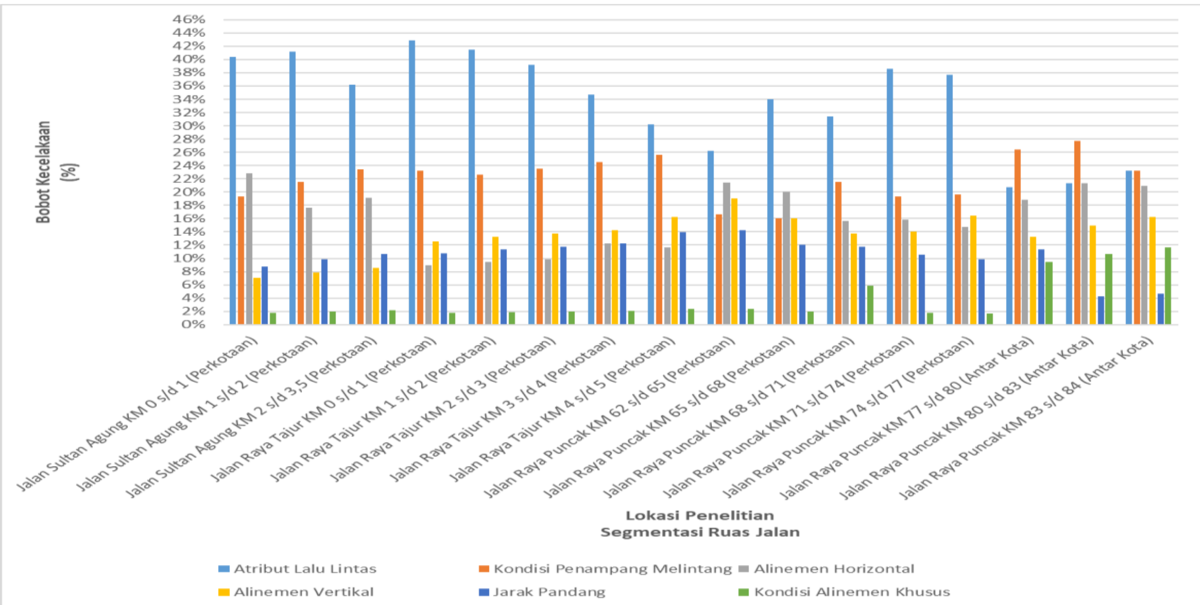
KM	TOTAL EAN (2018-2023)	UCL	RANKING OF ACCIDENT-PROVEN LOCATIONS
4-5	270	768	5
3-4	525	780	4
2-3	575	782	3
1-2	1100	798	2
0-1	1220	802	1
Total	**3690**		
Average	**738**		

Recapitulation Results of Weighting, Probability, EAN, UCL Values on 4 Road Sections

The results of the recapitulation of weighting values can be seen in Figure 4 below.

Figure 4

Comparison of Accident Weights Based on Main Parameters Between Road Segmentations



The weight of accidents on urban roads is influenced by Traffic Attributes by 26-43%. Theoretically, this can happen because many vehicles at high speed pass through urban roads. So this result is a new discovery in this discussion, because in Idalin et al (2018) it is only used for inter-city roads.

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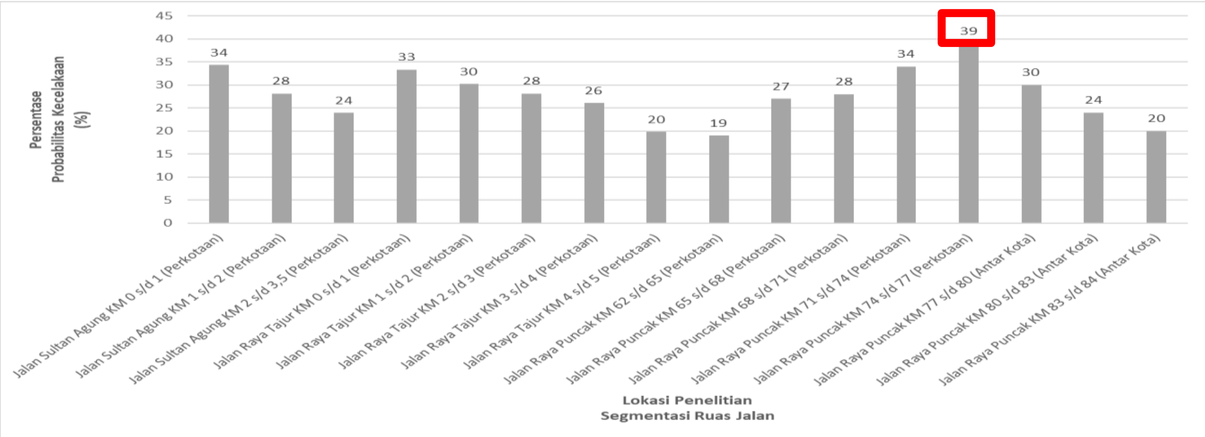
Another result obtained from Figure 4 above is that the weight of accidents on inter-city roads is influenced by Cross Section Conditions by 23-28%. Theoretically, this can happen because inter-city roads have relatively narrow existing road conditions with slopes/mountains/cliffs on either side that are dangerous for motorists. These results are inversely proportional to the results of Idalin et al (2018) which stated that inter-city road accident parameters were caused by the Traffic Attribute group. So these results are new findings in this discussion.

The results of the recapitulation of probability values using the Idalin et al (2018) method can be seen in Figure 5 below.

Figure 5

Recapitulation of Comparison of Accident Probability Percentage Values Between All Road Segmentations

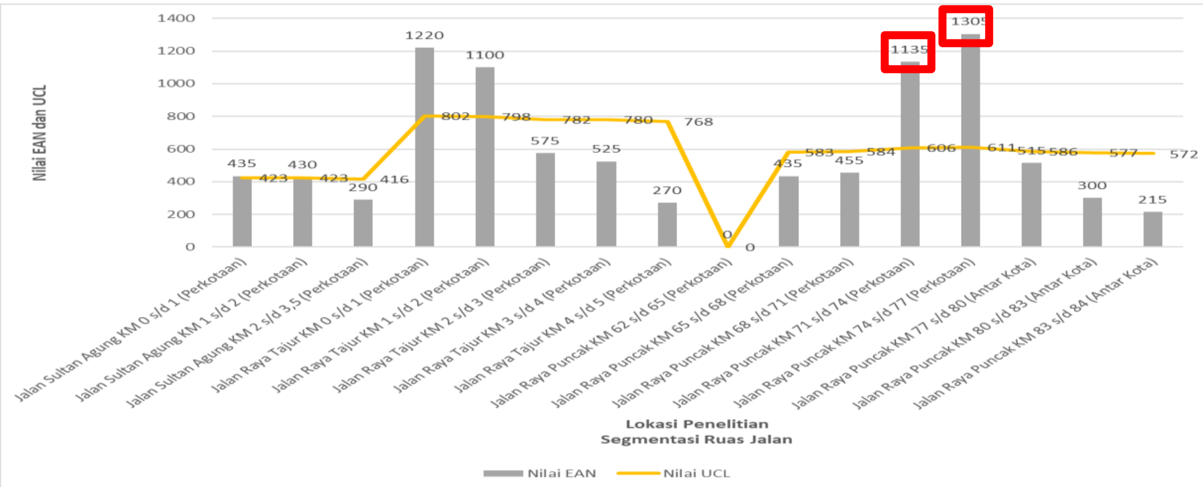


Road sections that have a high probability of accidents are Jalan Raya Puncak STA 74+000-77+000 with 39% medium category (Table 2 above) with characteristics of national road section status, primary collector function, road class I, urban area type, slope. hilly road terrain (10-25%).

The results of the recapitulation of EAN and UCL values using the calculations of Susilo et al (2019) can be seen in Figure 6 below.

Figure 6.

Recapitulation of comparison of EAN and UCL values between all road segmentations



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The highest results were obtained on the Jalan Raya Puncak (Urban) section, there were 2 out of a total of 5 segments that had an EAN value exceeding the UCL value limit (red box), namely KM 71-74 with a value of 1136 versus 606, then KM 74-77 with a value of 1305 versus 611. These two segments are priorities for handling accident-prone locations.

Relationship between Probability Value (X) and EAN Value (Y) on Each Road Section

After getting the EAN value and probability value, a statistical test is needed using a simple linear regression test. This test was chosen because it is a type of looking for a relationship between 2 variables. Obtained using SPSS software, the results can be seen in **Table 6** below.

Table 6

Relationship between Probability Values and EAN Values for Each Road Segment Characteristic

Section	Characteristics	R^2	Regression Equations
Jalan Sultan Agung Bekasi City	National; Urban; Primary Arteries; Class I; Flat Road Terrain Gradient (<10%)	0.91	EAN = 48.2*Prob – 813.9
Tajur Highway Bogor city	National; Urban; Primary Arteries; Class II; Hill Road Terrain Gradient (10-25%)	0.85	EAN = 73.6*Prob – 1287
Puncak District Highway. Bogor	National; Urban; Primary Collector; Class III; Hill Road Terrain Gradient (10-25%)	0.96	EAN = 70.1*Prob – 1395
Puncak District Highway. Bogor	National; Intercity; Primary Collector; Class III; Mountain Road Terrain Gradient (>25%)	0.98	EAN = 30.4*Prob – 408

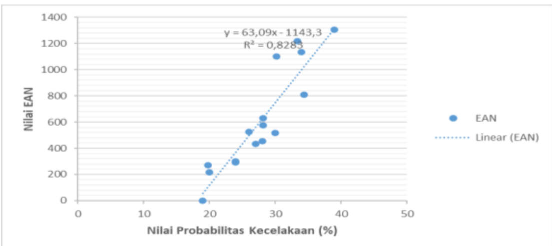
r^2 value is 0.98 on the Jalan Raya Puncak section with inter-city characteristics. This is in accordance with the objectives of Idalin et al (2018) who created a model for inter-city roads. Meanwhile, road sections with characteristics other than intercity are new findings in this research that can be used because they have a high correlation .

Regression Equation for All Road Segments

The results of the regression equation for each road segment characteristic shown in Table 6 above with a total of 16 pieces of data can be reprocessed to produce a regression equation that can be used for all national road section statuses. Obtained using SPSS software, the results can be seen in Figure 7 with the regression equation, namely EAN = 63.09*Prob – 1143.

Figure 7

Relationship between EAN Value and Accident Probability Value for National Road Status.



From the results of the image above, we have several conclusions that the Probability Value (Variable X) to the EAN Value (Variable Y):

a. Has a Linear Regression Correlation Analysis Test result of 0.82 (high correlation);
b. It has a positive direction, so that the greater the Probability Value, the greater the Equivalent Accident Number (EAN) Value;
c. The Upper Control Limit (UCL) value is influenced by the Equivalent Accident Number (EAN) value. The greater the EAN value, the greater the UCL value;
d. The greater the probability value, the greater the EAN and UCL values.

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A segment of road that has a high probability, EAN and UCL are priorities for handling accident-prone locations, so that they can be followed up by local and related governments to take preventive action. All road sections have different probability results because there are differences in status, function, class, area type and road terrain slope which of course influence the value of each parameter.

Preventive actions that can be taken before an accident occurs again are by trying to reduce the value from the original maximum value (value 5) to the minimum value (value 1). For example, an existing section of road . Of course, parameter changes need to be adjusted to the conditions of the surrounding existing land.

4. Conclusion

In the 5 years since the Idhalin et al (2018) method was issued, there have been updates to the regulations above 2018, namely changes to 2 laws; addition of 1 PP, Presidential Decree, PUPR Ministerial Regulation; changes to 2 PUPR Ministerial Regulations and 3 Transportation Ministerial Regulations; changes to 4 Public Works Sector Guidelines/Manuals. Regulatory changes may affect the number of parameter adjustments that can be developed in other research . The highest accident probability based on the Idalin et al 2018 method is 39% (medium category) on Jalan Raya Puncak KM 77 to KM 80 (National; Collector; Class III; Medan Bukit; Urban) . There is a high correlation between the probability value and the EAN and UCL values, the greater the probability value, the greater the EAN and UCL values . The weight of urban road accidents is influenced by traffic attributes by a maximum of 43%, while on inter-city roads it is influenced by cross-sectional conditions by a maximum of 28%.

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