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MULTI VARIABLE ROAD FATALITY PREDICTION STUDY IN CITY AREA BY USING ANDREASSEN AND ARTIFICIAL NEURAL NETWOKS MODEL DEVELOPMENTS IN WEST JAVA, INDONESIA

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ABSTRACT

Data on fatality traffic accident victims has not been fully identified in Indonesia and might have most likely been unreported. Republic of Indonesia Traffic Ordinance Number 22 Year 2009 stated that fatality data must be completed with hospitals' data. However, the data reported by Republic of Indonesia Police has not been in accordance to the law. It causes the data to be inaccurate and unfit to be referred in the study of road safety. In many countries, researchers have been using population and motor vehicles numbers as variables to predict fatality victims' number. Those variables are not fit with Indonesian condition that have the vastest areas, the densest population, the longest road infrastructure, and the largest numbers of motor vehicle users in ASEAN countries. The main purpose of the study was to develop better fatality prediction model in line with Indonesian condition. This was done by developing multivariable Andreassen and Artificial Neural Network models. The model was built by using population data taken from 8 cities in West Java Province, Indonesia in 2007-2010. Main results from model validation test are: (1) three variables ANN with one hidden layer prediction model was the best prediction used for to predict fatality numbers; (2) Fatality number was 122.8% bigger than that fatality data reported by Republic of Indonesia Police, that was, 956 people; (3) Andreassen prediction model was unfit to be used in Indonesia. The results were recommended as the newest prediction models to be used in the road safety study in Indonesia.

Keywords: Fatality data, multivariable, Andreassen model, Artificial Neural Network (ANN) model, Indonesia

INTRODUCTION

Accurate number on fatality traffic accident victims has not been fully identified in Indonesia and in fact fatality data reported by Republic of Indonesia (RI) police has not yet reflected the real situation. The data reported comes from accident scenes and is uncompleted with victims data died in hospitals. RI Traffic Ordinance number 22 Year 2009 stated that fatality data must be completed with that hospitals'. Asian Development Bank (2005) reported that Indonesia fatality number is actually four times larger than that reported in RI police data, assuming that there are still many victims' unrecorded and most likely unreported indicating under-reporting data. These inaccuracies are unfit to be used in many road safety studies in order to apply startegic policy to maintain road safety management system in the country.

In many countries including Indonesia, road safety researchers generally predict fatality number by using prediction models developed by Smeed (1949) and Andreassen (1985) in Europe. Those models are designed based on two variables namely population and motor

vehicle numbers. Compared to other ASEAN countries, Indonesia has the densest population, the highest number of motor vehicles, the longest road infrastructure and the vastest land, but, the lowest fatality number. This condition is irrelevant with Smeed and Andreassen prediction models assumption using two variables. Thus, this study aims to build fatality prediction model in line with Indonesian condition; that is, from two variables become multivariable. These multi variables include road length, population, motor vehicles, and vast area. These are built by developing Andreassen and Artificial Neural Network (ANN) prediction models in order to attain the newest fatality prediction model which is in line with Indonesian condition this newest model is expected to be more accurate in predicting factual fatality data.

Traffic Accident Fatality Record in Indonesia

Data recording of traffic accident victims in Indonesia is entrusted by RI Traffic Ordinance number 22 Year 2009 section 233 stating that every traffic accident must be recorded in traffic accident form that constitutes a forensic data. Traffic accident data is managed by RI Police and must be completed with data from hospitals to be used by Traffic and Public Transportation Affairs Officer in the country.

The intended data is data of traffic accident fatality, serious injury and slight injury victims. International Road Traffic and Accident Database (IRTAD, 1998) defines fatality as traffic accident victims fell dead or died within 30 days since the accident occurred. However, contrary to what the law regulated, RI police has not yet enforced the law. The data recorded by RI police is uncompleted with that from hospitals.

The results of study and analysis of transportation experts in Indonesia and international institutions showed that Indonesia faces serious problem with recording numbers of traffic accident victims bearing the assumption of unrecorded and unreported victims. RI Relation Department (2004) stated that RI Police records victims' number died in the scene, however, RI Health Ministry and hospitals do not report fatality number within 30 days after the accident to the RI Police. Recording group by each institution results in different data information filed for the same accident. In 2007, Indonesian Transportation Society reported that appointed institutions in the country to record traffic accident victims are not well cooperated. Each institution works in solitude and ignores partnership, results in poor road safety management system and high rate of traffic accident. Traffic accident victims data reported by RI police is unreliable viewed from its low number of accident victims and therefore is not factual. In countries where road safety is prioritized, information collection of traffic accident as data base becomes significant and reliable accuracy. Therefore, the main purpose of this study is to build multivariable fatality prediction model in line with Indonesian condition, as well as to predict number of traffic accident fatality victims.

CONTEXT AND REVIEW OF LITERATURE

Road Fatality Data in ASEAN Countries

WHO (2009) reported that 30.000 people averagely died due to traffic accident. In ASEAN countries, Indonesia holds the third highest rank in position in terms of fatality victims. Hobbs (1995) illustrated that traffic accident cases are difficult to reduce and incline to increase along with road length and number of vehicles movement. RI Relation Department (2004) stated that Indonesia occupies the poorest traffic accident victims recording system, in the tenth of ten ASEAN countries. Table 1 below shows data in ASEAN countries in year 2007.

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Table 1. Fatality Data in ASEAN Countries 2007 (WHO, 2009)

Country	*Population*	*Number of Vehicle*	*Fatality Reported*	*Estimation*
Cambodia	14.443.679	154.389	1.668	
Indonesia	231.626.978	63.318.522	16.548	37.438
Malaysia	26.571.879	16.825.150	6.282	
Singapore	4.436.281	851.336	214	
Thailand	63.883.662	25.618.447	12.492	
Vietnam	87.375.196	22.926.238	12.800	

Fatality Data in Road Fatality Study

In road safety study, traffic accident fatality data is primary data. Fatality data accuracy is needed to obtain relevant study results with factual data in the field. The study result is useful for the settlement of strategic policy, among others are law enforcement, road safety management system to reduce traffic accident risks, black spot maintenance, road safety action planning program and program evaluation setting before the implementation, ongoing and in the future. If the road safety is conducted by data input with low accuracy, the output of the study will not show factual condition, will not attain target to maintain an expected condition. In other words, the result is unreliable.

Andreassen Prediction Model (1985)

Andreassen developed Smeed Prediction model (1949) by adjusting intercept and gradient parameter from Smeed equation in general pattern:

$$F = C \times V^{M_1} \times P^{M_2} \quad \ldots\ldots\ldots (1)$$

In which:

F = fatality prediction number
C = Constanta
V = Number of Motor vehicles
P = Number of population
M_1 = coefficient degree of number of motor vehicles
M_2 = coefficient degree of number of population

Andreassen model needs calculation of Constanta C, coefficient M_1 and M_2 by searching the values of α, β dan γ using double linier regression analysis resulted in :

$$F = e^{\alpha} \times V^{\beta} \times P^{\gamma} \quad \ldots\ldots\ldots (2)$$

Artificial Neural Network Model (ANN)

Artificial Neural Network Model (ANN) is a model instrument of non-linier statistical data that can be used to model a complex relationship between input and output to seek patterns. Artificial Neural Network Model model has been oftentimes implemented in many field of science to predict (William dan L.Yan, 2008). There are three types of Artificial Neural Network Model model namely Multi Layer Perceptron (MLP), Radial Basis Function (RBF),

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and Kohoren Network (KN). In terms of prediction problems, MLP model is the most used model to map out a set of input data to become a set of output data by applying non-liner activation function. In MLP, both Independent and dependent variables have three levels of metric and non-metric measures. MLP is also known as forward network or back-propagation as the information moves in one direction that is from input layer to hidden layer then to output layer (see Figure 1)

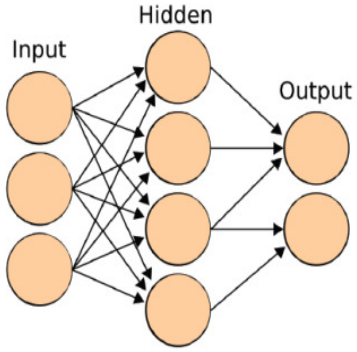

Figure 1. ANN Multi Layer Perceptron Prediction Model (MLP)

Activation Function in hidden layer is:

Hyperbolic tangent: $Y(c) = \tanh(c) = \frac{e^{c} - e^{-c}}{e^{c} + e^{-c}}$ ……. (3)

Sigmoid: $Y(c) = \frac{1}{1 + e^{-c}}$ ……. (4)

Activation Function in output layer is:

Identity: $Y(c) = c$ ……. (5)

Softmax: $Y(c_k) = \frac{e^{c_k}}{\sum_j e^{c_j}}$ ……. (6)

Hyperbolic tangent: $Y(c) = \tanh(c) = \frac{e^{c} - e^{-c}}{e^{c} + e^{-c}}$ ……. (7)

Sigmoid: $Y(c) = \frac{1}{1 + e^{-c}}$ ……. (8)

Model Validation Test

Model validation test is conducted mathematically by using three types of error model test criteria, namely Mean Absolute Percent Errors (MAPE), Mean Absolute Errors (MAE), and Root Mean Square Errors (RMSE) with the following formulas:

$$MAPE = \frac{1}{n}\sum\left(\left|\frac{o_j - t_j}{o_j}\right| \times 100\right) \text{……. (9)}$$

$$MAE = \frac{1}{n}\sum\left|t_j - o_j\right| \text{……. (10)}$$

$$RMSE = \sqrt{\frac{1}{n}\sum\left|t_j - o_j\right|^2} \text{……. (11)}$$

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The best prediction model is the one having the smallest difference from actual fatality data. This is taken by fatality number data by RI police is added with victims data of traffic accident died in the hospital.

METHODOLOGY

Study Area Location

The location of the study was in West Java Province, Indonesia consisting of 26 regencies/ cities. Compared to other provinces in Java Island, in 2010, West Java was a densely-populated area (43.806.653 people), it had the most number of motor vehicles (9.069.704 vehicles unit, it occupied the longest road (27.128.52 kilometer) with the width of the area was 38.783, 13 km^2. Further, at that time, West Java had also the highest rate of traffic accident as many as 9409 occurrences.

Population and Sample of Study Area

Eight city areas as a total number of cities in West Java province were used in the study. In terms of hospital sample, center general hospitals in West Java Province and 7 Regional General Hospitals also in the same area were employed as sample of the study. Hospital classification was Class B based on its medical service facilities in the province. Table 2 below shows 8 cities area and hospitals as population/ sample of the study, while Table 3 demonstrates hospitals criteria specifications.

Table 2. City and Hospital Population/ Sample

City Area	*Hospital Sample*
Bandung	1. Dr Hasan Sadikin Bandung Hospital
	2. Al-Islam Bandung Hospital
	3. Adventist Bandung Hospital
	4. Immanuel Bandung Hospital
Depok	5. Depok Regional General Hospital
Cimahi	6. Cimahi Regional General Hospital
Bogor	7. Bogor Regional General Hospital
	8. Bogor PMI (Indonesian Red Cross) City Hospital
Sukabumi	9. Sukabumi Regional General Hospital
Tasikmalaya	10. Tasikmalaya Regional General Hospital
Cirebon	11. Cirebon Regional General Hospital
West Bandung	12. West Bandung Regional General Hospital

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Table 3. Hospital Classification

No	*Medical Service Facilities Type*	*General Hospital Classification based on Medical Services Facilities Ability*			
		Class A	*Class B*	*Class C*	*Class D*
1.	Emergency Services	√	√	√	√
2.	General Services	√	√	√	√
3.	Basic Specialists Services	min 4	min 4	min 4	min 2
4.	Medical Supporting Specialists	5	4	4	---
5.	Sub-Specialists Services	12	8	---	---
6.	Other Types of Medical Specialists	13	2	---	---

Source: RI Laws Number 44 Year 2009 Regarding hospital

Prediction Model Development and Research Variables

This study employed Andreassen (1985) and Artificial Neural Network prediction models with fatality prediction multivariable in Indonesia. There were two variables of Andreassen used including numbers of motor vehicles and population. On the other hand, Artificial Neural Network employed four types of variable namely, population and vehicle numbers, and accessibility (variable ratio of road length to that of area width). Table 4 below illustrates input data in each model and research variable used.

To obtain the best prediction model, mathematical test was conducted by using three types of criteria error model test MAPE, MAE, and RMSE. The best prediction model was the one with the smallest difference error value.

Table 4. Research Variable and Input Data

Research Variable	*Total Input data of all study areas (per-year)*				*Input variable*	
	2007	*2008*	*2009*	*2010*	*Andreassen*	*ANN*
Population (Million)	25,18	25,72	26,15	27,80	√	√
Vehicle (million/unit)	4,54	5,12	5,70	6,74	√	√
Accessibility (road length ratio to that of area width)	0,64	0,79	0,80	0,86	×	√
Factual Fatality *)	1885	2045	2140	2541	√	√

*) RI Police Data + Survey results from Hospitals

Survey Technique of Fatality Data in the Hospital

Traffic accident victims' data died in the hospital was done by using document analysis of medical record each patient has. This was referred to RI laws Number 14 Year 1993 regarding Road Traffic and IRTAD (1998) stating that the length of nursing care is 30 days maximally after the accident occurred. Figure 2 illustrates stages of patient medical record document analysis in the hospital.

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Fatality Prediction Model Development Procedure

Fatality Prediction Model Development Procedure was built based on different types of input data from all variables. Afterwards, model development was conducted by using general equation from Andreassen (1985) and ANN model developments from MLP form. Figure 3 illustrates fatality prediction model development process.

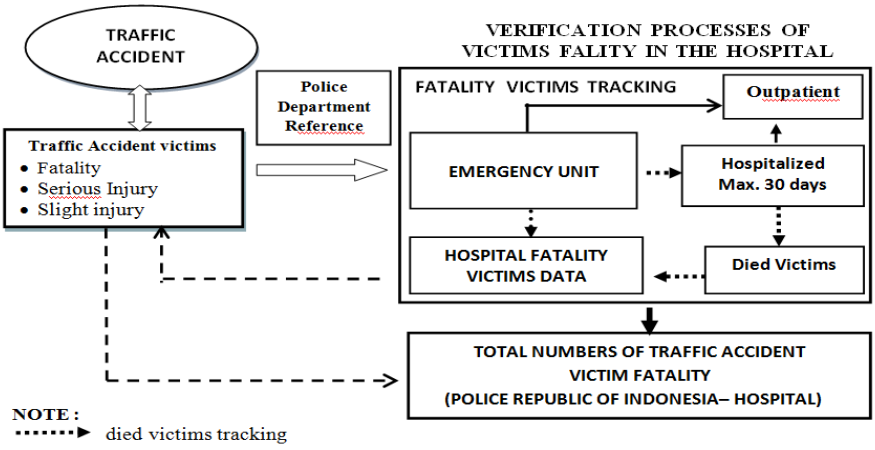

Figure 2. Stages of Fatality Survey Data in Hospital

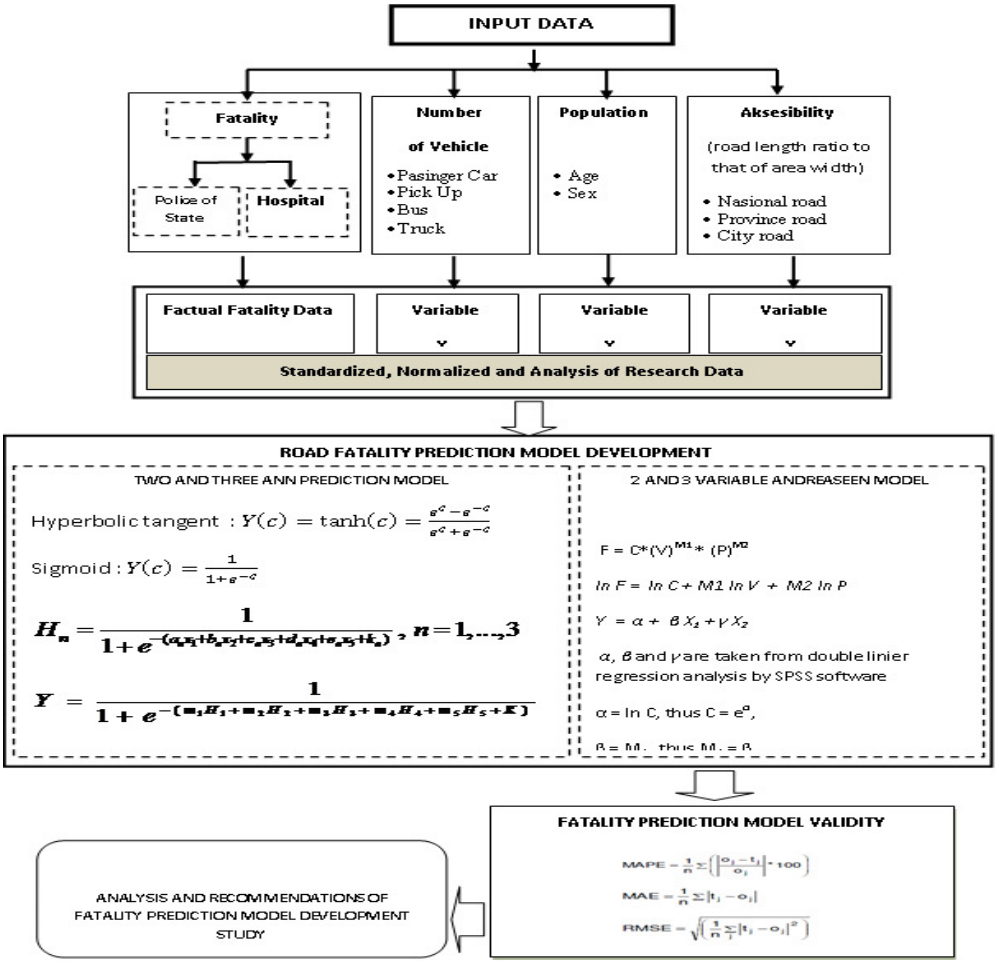

Figure 3. Fatality Prediction Model Development Process

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RESEARCH RESULTS AND DISCUSSION

Fatality Prediction Model Development Result

Table 5 illustrates the summary of research on Andreasen (1985) and ANN model developments with one and two hidden layer and multi-variable in line with Indonesian condition.Each model was provided with fatality number prediction occurred in 2010 in 8 big cities in West Java Province in Indonesia. Andreassen model application (FA) was done based on Andreassen general equation form with two variables input data namely population and motor vehicles numbers. Meanwhile, Andreassen (F1), (F2), and (F3) model development with multi-variable input data was conducted based on inter-variables relation analysis. Those inter-variables relation were relation between driver behavior and fatality number by using two step cluster, between accessibility variable relation (road length ratio to area width) and fatality number, between mobility relation (road length ratio to 1000 population number) and fatality number, relation between population and motor vehicles number and fatality number. Relation inter-variable analysis was also conducted to ANN model development.

Tabel 5. Summary of Fatality Prediction Model Development in 8 Big Cities in West Java Province, Indonesia

	Prediction Model and Fatality Number						
Name of City	*Factual Fatality*)*	*Model Andreassen (FA)*	*Dev1 Andreassen (F1)*	*Dev2 Andreassen (F2)*	*Dev3 Andreassen (F3)*	*ANN 3 Var 1 HL (F3-1)*	*ANN 3 Var 2 HL (F3-2)*
Bandung	780	363	418	557	596	609	553
Depok	130	258	255	250	272	210	219
Cimahi	197	217	190	231	249	186	193
Bekasi	306	386	345	321	377	353	364
Bogor	337	269	297	288	274	320	331
Sukabumi	172	149	157	146	124	154	159
Tasikmalaya	146	157	162	148	132	149	153
Cirebon	141	214	150	148	152	149	151
Total	2209	2013	1974	2089	2176	**2130**	2123

*) RI Police report =956 , Survey Results from hospitals= 1253,

**) Development models

Table 5 illustrates the summary of prediction model development results in 8 big cities in West Java Province Indonesia.

From error model test validation result using three types of criteria namely MAPE, MAE and RMSE, it was found that one hidden layer (1HL) ANN prediction model was the best model occupying the smallest error value compared to other model predictions. From 3 variable one layer ANN prediction model, it was found out that fatality number prediction occurred in 8 cities of West Java Provinces was 2130 people in 2010 in the following equation form:

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ANN3-1HL Prediction Model :

$$F_{31} = 100 + 680F_{31}'$$

$$F_{31}' = 2.077 - 2.17H_{31(1:1)} - 0.115H_{31(1:2)}$$

$$H_{31(1:1)} = \frac{1}{1+e^{-(2.723-0.607V'-0.834P'-1.615A')}}$$

$$H_{31(1:2)} = \frac{1}{1+e^{-(-0.262-0.583V'-0.412P'-0.09A')}}$$

Table 6 is all six models validation test developed in the study, in which 3 variable one hidden layer (ANN3-1HL) ANN prediction model was the best model prediction in line with Indonesian condition.

Table 6. Models Validation Test

Validation Criteria	*Models Validation Test*					
	Model Andreassen	*Dev1 Andreassen*	*Dev2 Andreassen*	*Dev3 Andreassen*	*ANN 3 Var 1 HL*	*ANN 3 Var 2 HL*
	(FA)	(F1)	(F2)	(F3)	(F31)	(F3-2)
MAPE	15,62	10,93	9,95	13,69	7,09	7,77
MAE	45,56	34,06	26,44	32,50	19,72	23,00
RMSE	107,41	91,41	61,75	61,62	46,34	59,25

DISCUSSION

Table 5 and 6 above explain that ANN3-1HL model validation test result has the smallest MAPE, MAE and RMSE error compared to two variables Andreassen prediction model (FA), and multi variable Andreassen model development result was in line with Indonesian condition (F1,F2,F3), namely MAPE = 7.09, MAE = 19.72 and RMSE = 44.34. ANN3-1HL model was found out capable of predicting fatality number occurred in 8 big cities in West Java Province in 2010 as many as 122.803% from the figure reported by RI police as many as 956 people. This figure has shown that 122.803 fatality data was under reporting by RI police. In terms of ANN3-1HL model factual fatality data; it was found out that this model was capable of disclosing fatality data as many as 96.424 % from 2209 people. This condition was in line with Asian Development Bank (2005) report stating that fatality number in Indonesia was not fully identified as there were still many traffic accident victims unrecorded and unreported by RI Police.

Compared to result of two-variable Andreassen model use with the ignorance of validation test result, Andreassen model was still able to predict fatality number occurred in 2010 as many as 110.565 % to the data reported by RI Police, or 90.89% prediction number to factual fatality data. From the result of multi variable (F1), F2), (F3) Andreassen prediction model development, it was found that all three models were the highest in their error value validation test. This was reflected by the average values of MAPE = 11.52, MAE = 31 and MRSE = 71.59. Compared to ANN3-1HL prediction model, Andreassen prediction model was not fit to be used in Indonesia because it has the longest road infrastructure and vast areas in ASEAN countries.

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CONCLUSION

Based on fatality prediction model development result and discussion analysis of study results above, it can be concluded that:

1. Three-variable with one hidden layer *Artificial Neural Network* (ANN3-1HL) prediction model is the best prediction model that can be used to predict number of victims died due to traffic accident in 8 big cities area in West Java Province, Indonesia.
2. Victims' number died because of traffic accident in 8 big cities in West Java Province, Indonesia as many as 2130 people in 2010. Fatality number was 122.8% bigger than fatality data reported by RI Police as many as 956 people.
3. Andreassen prediction model (1985) with two variables was used to predict factual fatality number occurred in the field. This was not fit to be used in Indonesia that has the longest road infrastructure and the vastest area.

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