Driving Performance at Low Visibility-Case Study: Banyumanik-Bawen, Indonesia Toll Road

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Abstract- Bad weather is one of the factors that cause traffic accidents. Accidents happen because visibility decreases when bad weather occurs. In order to prevent accidents, roads need to be installed traffic signs. One type of traffic sign is a Variable Speed Limit (VSL). In this study, the relationship between driver compliance and VSL (when driver's visibility is reduced) is measured and analyzed. Primary data was collected by filling out a closed questionnaire with a Likert scale of 1-5. The total respondents in this study are 130 people who have passed the Banyumanik-Bawen toll road. Primary data in this research is analyzed by Structural Equation Modeling (SEM) method. The first result, human factor and VSL satisfaction are significant to driver compliance during any weather conditions. The second result, driver compliance during fog or mild rainy weather conditions, is only influenced by human factors. In conclusion, when bad weather conditions human factors and satisfaction with VSL together affect driver compliance.

Keywords- Safety Transportation, Low Visual, Variable Speed Limit

I. INTRODUCTION

Transportation is the transfer of goods and people from the place of origin to the destination [1]. Transportation is something inseparable from human life. In this era of globalization, technology and transportation are growing rapidly. The progress of transportation makes it easier for humans to reach distant destinations. Another impact is the modern society in droves of having private cars. As the number of personal cars increases, the most basic thing that the driver needs to pay attention is the safety of driving to avoid accidents. Although toll roads are considered as roads with relatively more ideal conditions compared to arterial road conditions in general, it turns out that the toll road is still prone to accidents.

The causes of traffic accidents can be grouped into four elements: human, vehicle, road, and environment [2]. Environmental factors are factors that need to be noticed by the driver. What is meant by environmental factors is the weather conditions, namely misty and rain. Poor weather conditions have a significant impact on vehicle performance, driver's visibility, driver behavior, travel demand, traffic flow characteristics, and traffic safety [3]. Weather conditions can affect the driving force. The first condition, low visibility is the driver who becomes more careful and lower the speed. The second condition, there are drivers who do not care about the situation and remain with a high speed. The second condition can cause an accident.

Semarang-Solo toll road (Indonesia) is a toll road connecting the cities of Semarang, Salatiga, and Surakarta. The toll road consists of 5 sections. Two sections that have been running are 1 Banyumanik-Ungaran section and 2 Ungaran-Bawen section. While other sections are still in the stage of construction and land acquisition. Semarang-Solo toll road is located in the mountains, weather conditions are things that need to be considered. Like the news written in Kompas [4], an accident occurred in the Semarang-Solo toll road section KM 25 + 350 Ungaran-Bawen toll road allegedly caused by heavy rain and limited visibility. According to the supervisor of Traffic Services Unit PT. Trans Marga Jateng (TMJ), Agus Pramono, Banyumanik-Bawen toll road during 2014 there are 75 cases of accidents that occurred with the current of vehicles reaching 600 thousand vehicles per month. Most of the accidents are caused by lack of driver anticipation (for example, not obeying traffic rules in terms of speed, drowsiness, or tire skid) [5]. Based on the number of accidents obtained from PT. TMJ, the number of accidents occurring on the Banyumanik-Bawen toll in 2014: 75 accidents and 2015: 52 accidents.

Efforts that can be done to minimize accidents on the highway is the installation of traffic signs. One of the traffic signs is the variable speed limit (VSL). VSL is an Intelligent Transportation System (ITS) solution that enables information about the dynamic changes in the speed limit of a vehicle in response to traffic conditions, an incident, or weather conditions [6]. This research is a development of Hassan and Abdel-Aty [3] research. In Hassan and Abdel-Aty's research there are three general hypotheses where each hypothesis has a model. However, this study focuses only on hypotheses about driver compliance with VSL. The method to be used is Structural Equation Modeling (SEM) because SEM can capture the complex relationship between observation and latent variables.

II. METHODS

A. Accidents

Accidents are unexpected instant events that generally happen very quickly. Accidents are also the culmination of an ill-fated series of events. If by any means this chain of events can be cut off, the possibility of accidents may be prevented [7]. Traffic accidents are events that occur in a traffic movement due to errors in the traffic-forming system, ie driver (human), vehicle, road and environment. The notion of accidents here can be seen as a condition that is inconsistent with accepted standards or treatments as well as omissions made by humans [8].

Accidents can be caused by road users (drivers and pedestrians), vehicle and road factors, and environmental factors [9]. Pignataro also stated that accidents are caused by a combination of some bad behavior factors from drivers or pedestrians, roads, vehicles, bad weather or bad views. Factors that cause accidents can be divided into three factors, namely [10]:

a. Road user factors (human)
b. Vehicle factors
c. Road and environmental factors

B. Environmental Factors

Land use conditions, weather and wind conditions and traffic arrangements are some components of environmental factors that affect the occurrence of accidents. Inadequate road environment can lead to driver comfort decreased so that the ability to control the vehicle will decrease as well. There are four factors of environmental conditions that can affect human behavior in driving so that the potential to cause traffic accidents:

a. The use of land and its activities, crowded areas, lenggang, where the reflex driver will reduce the speed or vice versa.
b. Weather, air, and possibilities seen eg during fog, thick smoke, heavy rain that can reduce the driver's visibility.
c. Facilities on the road such as traffic signs, traffic lights and traffic marks.
d. Flow and the nature of traffic, the number, kind, and composition of the vehicle will greatly affect the speed of travel.

C. Variable Speed Limit (VSL)

VSL is an Intelligent Transportation System (ITS) solution that enables information about the dynamic changes in the speed limit of a vehicle in response to traffic conditions, an incident, or weather conditions. The VSL system utilizes information systems on traffic flow, vehicle volume detection, and weather conditions on the road to determine the appropriate speed limits for current traffic and road conditions. The speed limit changes are informed by displaying on roadside signs or on VMS (Bidoura & Lina, 2015).

D. Structural Equation Modeling (SEM)

SEM is an analytical method combining factor analysis, structural model, and path analysis [11]. Thus, in the SEM analysis can be done three kinds of activities simultaneously, namely checking the validity and reliability of the instrument (related to confirmatory factor analysis), testing the relationship model between variables (related to path analysis), and activities to obtain a suitable model for prediction (related to regression analysis or structural model analysis).

SEM is a technique with a combination of path analysis and regression analysis that allows researchers to simultaneously test a series of interrelated relations between measured variables and latent constructs [12]. SEM analysis is a multivariate analysis that is complex because it involves a number of independent variables (independent variable) and dependent variable (dependent variable) are interconnected to form a model.

E. Research Model

The object of this research is the driver who has passed the toll Banyumanik-Bawen (Indonesia). Data obtained through the distribution of questionnaires on drivers who have passed the toll Banyumanik-Bawen (Indonesia) with purposive sampling technique. The distribution of questionnaires is done by distributing directly at Banyumanik-Bawen toll road rest area and online. Respondents will provide answers on a likert scale of 1 to 5, each indicating strongly disagree (1), disagree (2), neutral (3), agree (4), strongly agree (5) to each question in the questionnaire.

According to [12], some guidelines for determining sample size for SEM method are as follows:

1. When parameter estimation using maximum likelihood estimation method, the suggested sample size is between 100 and 200.
2. A total of 5 to 10 times the number of parameters present in the model.
3. Equals 5 to 10 times the number of manifest variables (indicators) of the entire latent variable.

In this study involves as many as 13 indicators so that if referring to the third rule then the required sample size is as follows:

- Minimum sample size 5 x 13 = 75 samples
- Maximum sample size 10 x 13 = 130 samples

So in determining the number of samples for this study using the maximum sample size of 130 samples. Because the first rule has been mentioned that the recommended sample size is between 100 to 200.
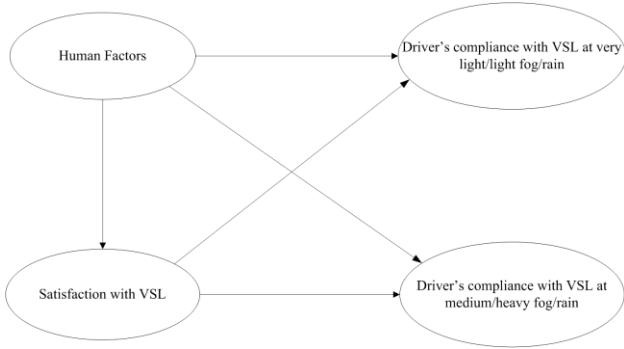
Figure 1.   Example of a figure caption. (figs caption)

F. Hypothesis

Conceptual models are needed to assist researchers in identifying relevant factors as well as the relationship between these factors. The conceptual model used in this study refers to the model built by Hassan and Abdel-Aty [3]. In Hassan and Abdel-Aty [3] studies three common hypotheses are used: driver compliance with VSL instructions, driver compliance with VMS instructions, and driver satisfaction with VMS and VSL instructions. Where each of these common hypotheses has their respective conceptual models broken down from the initial conceptual model. But in this study, the authors focus on only 1 hypothesis that is the compliance of the driver against VSL instructions so that the conceptual model used only 1 model only. Conceptual model can be seen in figure 1.

Based on the conceptual model for hypothesis 1 constructed by Hasan and Abdel-Aty [3], the following hypotheses can be compiled:

- Hypothesis 1: Human factors have a positive effect on driver compliance to VSL instructions during very light or light mist or rain conditions.

- Hypothesis 2: Human factors have a positive effect on driver compliance to VSL guidance during fog or moderate or heavy or heavy rainfall.

- Hypothesis 3: Human factors have a positive effect on driver satisfaction with VSL.

- Hypothesis 4: Driver's satisfaction with VSL positively impacts the driver's compliance to VSL instructions during very light or light fog or rain conditions.

- Hypothesis 5: Driver's satisfaction with VSL positively impacts the driver's compliance to VSL instructions during medium or heavy or heavy rain or rain conditions.

III.   RESULTS AND DISCUSSION

A. Conformity Test of the Structural Equation Model

This structural equation model is processed by using AMOS 20.0 software. Figure 2 is the result of testing full model. Evaluation of suitability model can be seen in Table 3. In table 1, it is known that there are some values of fit index which are Marginal or close to the value of cut off value. While goodness of fit test which can be said good is CMINDF, GFI, AGFI, and TLI.

Overall it can be concluded that the structural model can produce the expected level of estimation. According to Ghozali[11], if two or more of all Goodness of Fit used have shown a good fit model, then the model can be said to be good.
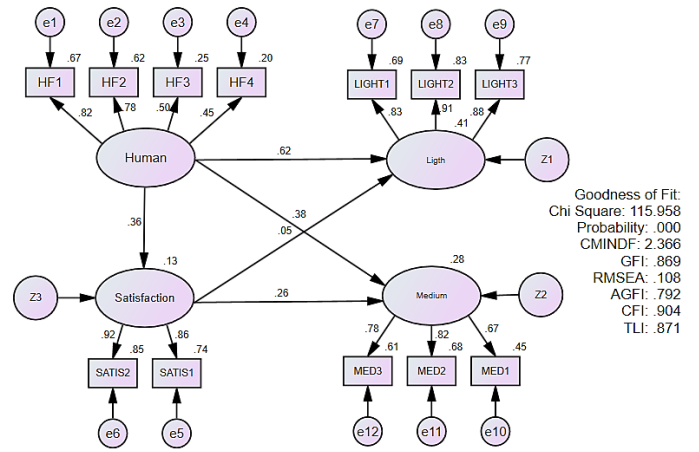

Figure 2.   Example of a figure caption. (figs caption)

TABLE I.   TABLE TYPE STYLES

Criteria	Result	Critical Value	Acceptable Match rate	Evaluation
Chi-Square	115.958	< 1159,760	$X^2/df > 5$	Marginal fit
CMINDF	2.366	≤ 3.0	-	Good fit
Probabilities	.000	≥ 0.05	-	Marginal fit
GFI	.869	≥ 0.90	(Poor Fit) 0 ≤ GFI ≤ 1 (Perfect Fit)	Good fit
RMSEA	.108	≤ 0.08	≤ 0.10 (Good Fit)	Marginal fit
AGFI	.792	≥ 0.90	(Poor Fit) 0 ≤ AGFI ≤ 1 (Perfect Fit)	Good fit
TLI	.871	≥ 0.80	Mendekati 1 (Very Good Fit)	Good fit
CFI	.904	≥ 0.95	CFI > 0.85 (Marginal Fit)	Good fit

B. Reliability Testing and Average Variance Extracted

The reliability test on the AMOS program is obtained by the formula:

$$CR= \frac{(\sum \text{standardized loading})^2}{(\sum \text{standardized loading})^2+ \sum ej}$$

Reliability test results for each research variable can be seen in table 2 follows:

TABLE II. TABLE TYPE STYLES

Variabel	ΣStandardized loading^2	ΣMeasurement Error	ΣCR	Cut-off Value	Hasil
Human Factors	1.7379	2.2621	0.7420	0.70	Reliable
DC Light	2.2897	0.7102	0.9061	0.70	Reliable
DC Medium / Heavy	1.7418	1.2582	0.8048	0.70	Reliable
Satisfaction	1.5878	0.4122	0.8849	0.70	Reliable

The Average Variance Extracted (AVE) value can be calculated using the formula:

$$Variance\ Extracted = \frac{\sum standardized\ loading^2}{\sum standardized\ loading^2 + \sum ej}$$

Where the standardized loading data used is the same as the data on the reliability test calculation. AVE test results can be seen in table 3 follows:

TABLE III. TABLE TYPE STYLES

Variable	Nilai AVE	Cut-off Value	Kesimpulan
Human Factors	0.434	0.50	Moderat
DC Light	0.763	0.50	Valid
DC Medium/Heavy	0.580	0.50	Valid
Satisfaction	0.793	0.50	Valid

C. Testing of Research Hypotheses

Testing this hypothesis is done by looking at this CR of each variable or probability value (p) the result of data processing and comparing it with the required statistical limit value. The required CR value is above 1.96 or its probability value is below 0.05 [13]. Testing the results of the hypothesis can be seen in table 4 follows:

TABLE IV. TABLE TYPE STYLES

	hypothesis	CR(>1.96)	P (<0.05)	Result
H1	HF → SATIS	3.146	0.002	Accept
H2	HF → LIGHT	5.374	0.000	Accept
H3	HF → MED	3.175	0.002	Accept
H4	SATIS → LIGHT	0.530	0.596	-
H5	SATIS → MED	2.328	0.020	Accept

Based on the results in table 4, obtained results recapitulation penngujian hypotheses that are not rejected, namely as follows:

1. H1: Human factors positively influence the driver's compliance to VSL instructions during very light or light mist or rain conditions. This result is in accordance with the results of research Hassan and Abdel-Aty [3].

2. H2: Human factors have a positive effect on driver compliance to VSL guidance during haze or heavy, heavy, or heavy rain. This result is in accordance with the results of research Hassan and Abdel-Aty [3].

3. H3: Human factors have a positive effect on driver satisfaction of VSL. This result is in accordance with the results of research Hassan and Abdel-Aty [3].

4. H4: Driver's satisfaction with VSL positively impacts the driver's compliance to VSL instructions during very light or light fog or rainy conditions. This result is not in accordance with the results of research Hassan and Abdel-Aty [3].

5. H7: Driver's satisfaction with VSL positively impacts the driver's compliance to VSL instructions during medium or heavy, heavy or heavy rain or fog conditions. This result is not in accordance with the results of research Hassan and Abdel-Aty [3].

IV. CONCLUSION

This study aims to analyze the conformity relationship of drivers to VSL when visibility is reduced due to adverse weather conditions. This research was conducted on the driver who had passed the Banyumanik-Bawen toll road. After doing research and data processing, it can be concluded that human factors and driver satisfaction to VSL have a significant relationship to the compliance of the driver to VSL during the weather conditions of fog or moderate rain, thick, or heavy. While the driver's compliance with VSL during fog or mild rain condition is only influenced by human factors.

From data processing, the variable that most influence driver's compliance to VSL on weather condition and any traffic is variable of human factors where the most influencing indicator is indicator of age. Young drivers, especially men, tend to overestimate their ability to drive and underestimate the risks of various conditions faced on the road (Matthews & Moran 1986 in Dejoy 1992).

To overcome this, the recommendations can be given is the enforcement of traffic law in the form of application of speed gun, installation of persuasive motogs on Variable Message Sign (VMS), counseling on the highway to drivers hit by tickets, and installation of street lights.

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