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Analyzing Vigilance Rate of Motor Vehicle Driver Using Regression and Structural Equation Modeling (SEM)

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A B S T R A K

Penelitian ini berfokus pada pengaruh perilaku berkendara berisiko, jalan monoton dan faktor kelelahan terhadap kewaspadaan pengemudi kendaraan bermotor. Pertumbuhan kasus kecelakaan di Indonesia setiap tahunnya sebesar 3,3%. Oleh karena itu perlu dilakukan kajian untuk meminimalisir risiko kecelakaan. Sampelnya berjumlah 100 responden. Kemudian data dianalisis menggunakan regresi dan Structural Equation Modeling (SEM). Analisis regresi menunjukkan bahwa variabel laten perilaku berkendara berisiko, variabel laten jalan monoton dan variabel laten kelelahan mampu menjelaskan variabel laten kewaspadaan sebesar 57,6%. Sedangkan hasil analisis SEM menunjukkan bahwa variabel laten perilaku berkendara berisiko dan variabel laten kelelahan mampu menjelaskan variabel laten kewaspadaan sebesar 75,3%. Nilai R square analisis SEM lebih tinggi dibandingkan analisis regresi. Terdapat beberapa penyebab terjadinya perbedaan R square antara analisis regresi dan SEM, yaitu: 1) multikolinearitas tidak diperbolehkan dalam analisis regresi, sedangkan dalam analisis SEM diperbolehkan; 2) tidak terdapat variabel laten pada analisis regresi, sedangkan pada analisis SEM terdapat variabel laten dan indikator variabel laten; 3) analisis regresi bersifat eksplanatori, sedangkan analisis SEM bersifat konfirmatori.

Kata kunci: Regresi; SEM; Variabel

A B S T R A C T

This study focuses on the impact of risky driving behavior, monotonous road and fatigue factor on vigilance of motor vehicle drivers. Accident case growth in Indonesia each year were 3.3%. Therefore it need to be conducted study to minimize the risk of accidents. The samples consist of 100 respondents. And then the data were analyzed using regression and Structural Equation Modeling (SEM). Regression analysis shows that latent variable risky driving behavior, latent variable monotonous road and latent variable fatigue can explain latent variable vigilance by 57.6%. Meanwhile, the result of SEM analysis show that latent variable risky driving behavior, and the latent variable fatigue can explain the latent variable vigilance by 75.3%. The value R square of SEM analysis are higher than regression analysis. There are several cause of differences of R square between regression and SEM analysis, namely: 1) the multicollinearity is not allowed in regression analysis, while it is allowed in the SEM analysis; 2) there is no latent variable in the regression analysis, while there are latent variables and indicators of latent variables in the SEM analysis; 3) the regression analysis is explanatory, while the SEM analysis is confirmatory.

Keywords: *Regression; SEM; Variables*

1. PENDAHULUAN

Road traffic accidents are caused by 3 factors including human, road and environmental as well as vehicle factor. The causes of accidents due to human factors include the characteristics of the driver, the behavior of the driver and pedestrians. The cause of accidents by road condition are very rare, because in

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general, traffic signs have been installed in dangerous locations that can lead to accidents. In general, accidents caused by vehicle factors include: conditions of brake, conditions of tire, and conitions of light vehicle.

Sleep less than 5 hours every night are almost 5 times more likely to have an accident due to falling asleep compared to accidents caused by other factors [1]. Sleep disorder tend to experience fatigue and tend to conduct several traffic violations compared to the driver who sleep normal [2]. Motorcycle driver who slept 6 hours or less than 6 hours were more likely to experienced an accident by 51%, meanwhile slept over 6 hours to 7 hours were more likely to have an accident by 27%, and then slept over 7 hours were more likely to have an accident by 22% [3].

In addition, fatigue and driver behavior are influenced by the driver's job, long duration of driving, work routine, driving at night, usong of stimulants, work schedule and speed [4]. Fatigue can cause of accidents and it usually occured between 12.00 - 18.00 [5]. In addition to, based on research was conducted in Australia, 1.9% of accidents due to fatigue and most of them occured between 14.00-16.00 [6]. The research was conducted in Australia shows that age, gender, work status, type of motor vehicle, drivers license status, fatigue, speed, and location of the accident influence the accident severity [7]. Fatigue can cause reduced ability of driver to drive the vehicle safely [8].

Several factors cause of fatigue on driver are lack of rest, long duration of driving, and monotonous roads [9]. Low traffic volume and monotonous road can cause early fatigue on driver [10]. Driving too long in monotonous condition or driving with lack of sleep condition can influence vigilance that has consequences on the ability to process visual surrounding information [11]. 80 minutes is the safe limit time for driving on monotonous roads [12]. 90 minute trip was a safe limit time for a monotonous highway driving [13]. Driving on roads which have roadside variability and driving on curvy roads would be able decrease the level of monotonous driving from 41% to 21% [14].

Attitudes toward traffic safety are directly associated with risky driving behaviors while having direct effects on attitudes toward traffic safety, personality traits are also found to influence risky driving behaviors indirectly mediated by traffic safety attitudes. Practical implications for traffic safety of young motorcyclists are also discussed [15]. Attitudes of drivers related to traffic safety are directly associated with risky driving behaviors and the characture of personality also influence risky driving behaviors indirectly mediated by traffic safety attitudes [15]. Reckless motorcyclists on the highway are 30% more likely to experience severely injuries in accidents [16].

Driver vigilance will increase when the drive in the curvy [17]. Driving too long at daytime in monotonous conditions can cause a continuous decrement in vigilance [18]. The distribution of the probability of accident severity is influenced by: sociodemographies of motorcyclists and several factors that influence speed behavior, suddenly collisions and driver vigilance [19]. Caffeine was more effective compared to placebo related to performance [20]. Energy drinks containing carbohydrates and coffee can increase driver vigilance and reduce occurrence of fatigue [21]. The use of the herringbones road markings can cause a significant improvement in the position of the riders' lane a treatment combining herringbones with chevron and repeater arrow signs can cause a reduction in speed [22].

The driver experience and vehicle familiarity factors can improve ability of driver to make variation of driving performance [23]. The drivers had (0–4 years) driving experience and drivers who had above 12 years driving experience are comparatively low in emotional violations but drivers had (4–12 years) driving experience are high [24]. The study that is conducted in Sweden on motorists show that drivers with good training and experienced will be able to drive automatically and more effectively compared to drivers with less experience [25].

Age, gender, driver experience, road conditions and characteristics of the vehicle factors can increase the risk of accidents [26]. Differences of motorcycle performance will affect the behavior of drivers and tend at risk of fatal accidents [27]. Among driver of 'light' motorcycle, age significantly affect accident severity and at-fault risk. Meanwhile the engine size significantly affect accident severity but not at-fault risk [28]. Driver aged above 55 years, male, under affect of alcohol, drowsiness, ROR to left/right on straight road more likely experienced fatal accident [29]. Drive at a speed of 20 km/hour causes a risk of fatal accidents by 5% while drive at a speed of 85 km/hour causes a risk of fatal accidents by 85% [30]. In addition, sports bikes drivers who involved in a fatal accident in Norway were caused by excessive speed [31].

Motor vehicles growth in Indonesia each year are quite high, amount at 6.49%. Based on data of Land Transportation Statistics shows that the number of motor vehicles in 2014 was 112,209,260 vehicles. In 2015 the number of motor vehicles increased by 121,394,185 vehicles. Then in 2016 the number of motorized vehicles increased by 129,094,823 vehicles. In 2017, the number of motor vehicles increased by 137,211,819 vehicles. Furthermore, in 2018 the number of motor vehicles increased by 146,858,759 vehicles [32].

Accident cases growth in Indonesia each year is quite high, amount at 3.3% [32]. Based on data of Land Transportation Statistics shows that the number of accident cases in 2014 was 95,906 cases. In 2015, accident cases increased by 96,233 cases. Then in 2016 the accident cases increased by 106,644 cases. In 2017, the number of accidents decreased by 104,327. Furthermore, the number of accident cases in 2018 increased again by 109,215 cases [32]. This study aimed to analyze several factors influence driver vigilance. Model of driver vigilance took human factor, road and environment, and vehicle into consideration. There are not many studies related to taking human factor, road and environment, and vehicle into consideration. The factors were analyzed simultaneously to obtain the model of driver vigilance in motor vehicle. Analyzing of data use regression and SEM.

2. MATERIAL DAN METODE

Location of study is in Indonesia. Approach method in this study is a quantitative method. The collection of data were carried out by distributing questionnaires through social media to motor vehicle drivers. The number of samples in this study were 100 motor vehicle drivers.

Analysis of data used regression and SEM. The variables in SEM consist of 2 variables, namely latent and indicator variables. Latent variables consist of several indicator variables. This latent variable is a variable that cannot be measured directly unless it is measured using an indicator variable. Latent variables consist of exogenous latent variables and endogenous latent variables. Exogen variables are independent variables that affect the dependent or endogen variable.

2.1. Regression

Regression analysis is a technique used to build an equation that connects the dependent variable (Y) and the independent variable (X). The simple form of the regression equation is Y = A + BX. Parameters A and B can be estimated using sample data drawn from the population. To get the regression equation, the first thing to do is to collect data from the variables that will be seen the relationship. To determine the regression equation, the least squares method can be used.

2.2. Measurement model

The measurement model describes the relationship between latent variables and indicators, as shown in Figure 1. Y variable is a latent variable that cannot be measured directly, and X1, X2 and X3 variables are indicators of the latent variable Y. X1, X2 and X3 variables are variables that can be measured.

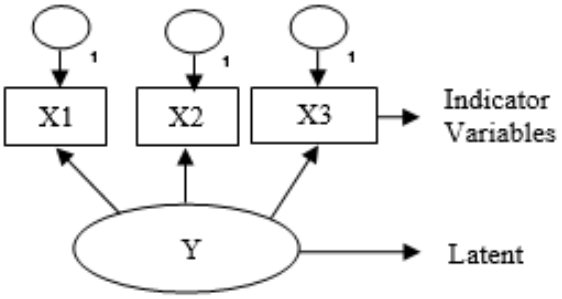

Figure 1. Correlation between latent and indicator variables

2.3. Structural model

The structure model describes the relationship between latent variables or between exogenous variables and endogenous variables as shown in Figure 2.

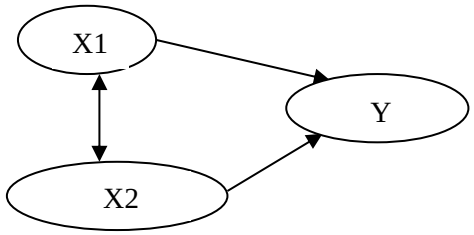

Figure 2. Example of structural model

3. RESULTS AND DISCUSSION

3.1 Regression analysis

The independent variables in this study are: risky driving behavior when driving (X1), feeling monotonous when driving (X2) and fatigue when driving (X3). Meanwhile, the dependent variable in this study is the driver's vigilance when driving (Y) as shown in Figure 3 below.

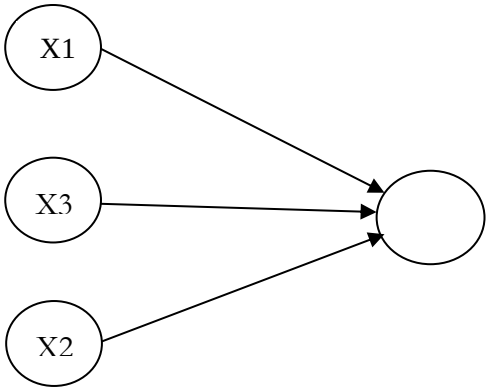

Figure 3. Model of driver vigilance

The results of statistical analysis, the correlation matrix between variables is obtained as shown in Table 1 below:

Table 1. Correlation between variables

	Y	**X1**	**X2**	**X3**
Y	1	0.599	0.588	0.676
X1	0.599	1	0.440	0.572
X2	0.588	0.440	1	0.522
X3	0.676	0.572	0.522	1

Based on Table 1 above, the relationship between the independent variable and the dependent variable is quite strong, while the relationship between the independent variables is not too strong. Then the result of statistical analysis was obtained regression equation as shown in Table 2 below:

Table 2. Vigilance model with regression analysis

Model	**F**	**R square**
Y=1,045X1+14,133	54,977	0,359
Y=1,142X2+17,347	51,833	0,346
Y=0,773X3+8,685	82,279	0,456
Y=0,736X1+0,791X2+10,366	46,592	0,490
Y=0,552X1+0,566X3+6,156	53,364	0,524
Y=0,628X2+0,580X3+7,215	55,255	0,533
Y=0,452X1+0,53X2+0,44X3+5,372	43,470	0,576

The results of statistical analysis show that there are 7 equations obtained. The first equation shows that Y = 1,045X1 + 14,133 with a value of F = 54,977 and a value of R square = 0.359, meaning that risky driving behavior can explain the alertness level amounted of 35.9% while 64.1% is explained by other factors. The more risky the driver's behavior when driving, the greater the decrease vigilance of driver. The second equation shows that Y = 1.142X2 + 17.347 with a value of F = 51.833 and a value of R square = 0.346, meaning that the monotonous road can explain the vigilance of driver amounted 34.6% while 65.4% is explained by other factors. The more monotonous the road, the greater the decrease vigilance of driver.

The third equation shows that Y = 0.773X3 + 8.685 with a value of F = 82.279 and an R square value = 0.456, meaning that the fatigue variable can

explain the alert level variable by 45.6% and 55.4% is explained by other factors. The more tired the driver when driving, the greater the decrease vigilance of driver.

The fourth equation shows that Y = 0.736X1 + 0.791X2 + 10.366 with a value of F = 46.592 and a value of R square = 0.490, meaning that the variable risky driving behavior and monotonous road can explain the alertness level of 49% and 51% is explained by other factors. The more risky the driver's behavior when driving, the greater the decrease vigilance of driver. The more monotonous the road, the greater the decrease vigilance of driver.

The fifth equation shows that Y = 0.552X1 + 0.566X3 + 6.156 with a value of F = 53.364 and a value of R square = 0.524, meaning that the variables risky driving behavior and fatigue can explain the alertness level of 52.4% and 47.6% is explained by other factors. The more risky the driver's behavior when driving, the greater the decrease vigilance of driver. The more tired the driver when driving, the greater the decrease vigilance of driver.

The sixth equation shows that Y = 0.628X2 + 0.580X3 + 7.215 with a value of F = 55.255 and the value of R square = 0.533, meaning that the momotonous road variable and the fatigue variable can explain the alertness level of 53.3% and 46.7% is explained by other factors. The more monotonous the road, the greater the decrease vigilance of driver. The more tired the driver when driving, the greater the decrease vigilance of driver.

The seventh equation shows that Y = 0.452X1 + 0.53X2 + 0.44X3 + 5.372 with a value of F = 43.470 and a value of R square = 0.576, meaning that the risky driving behavior variable can explain the alertness level of 57.6% and 43.4% is explained by other factors. The more risky the driver's behavior when driving, the greater the decrease vigilance of driver. The more monotonous the road, the greater the decrease vigilance of driver. The more tired the driver when driving, the greater the decrease vigilance of driver.

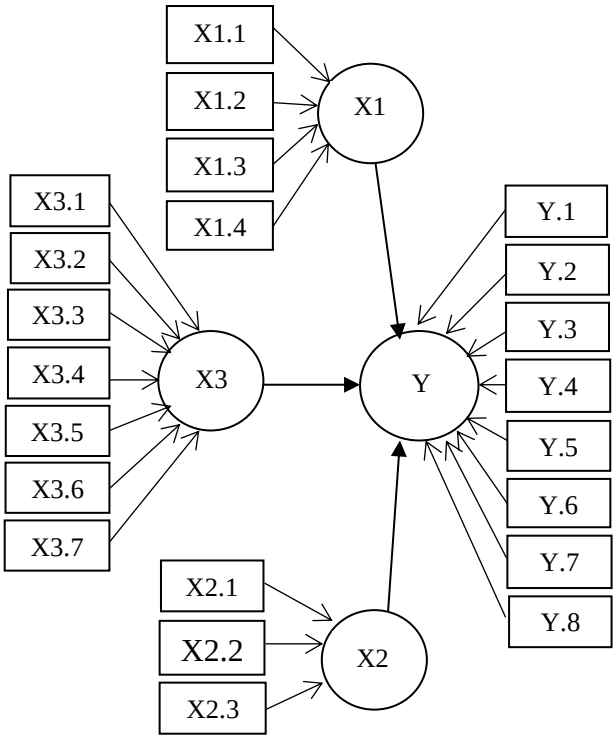

Figure 4. Vigilance model with SEM analysis

Notice: Y=driver vigilance, X1=risky driving behavior, X2=monotonous road, X3=fatigue, Y.1=coffee consumption, Y.2=driving on curve, Y.3=end of journey, Y.4=energy drink consumption, Y.5=road marking Y.6=monotonous road Y.7=straight road Y.8=get enough sleep, X1.1=age of driver, X1.2=engine capacity, X1.3=driver experience, X1.4=gender of driver, X2.1=long duration of driving, X2.2=roadside variability, X2.3=traffic volume, X3.1=driving time, X3.2=lack of rest, X3.3=long duration of driving, X3.4=monotonous road, X3.5=work routines, X3.6=work schedules, X3.7=types of work

Based on Table 2 above, the best regression equation is obtained, namely Y=0,452X1 + 0,530X2 + 0,440X3 + 5,372, where: F=43,47 and R square=0,576. The value of R square=0.576 indicates that X1, X2 and X3 variables can explain the Y variable by 57.6%, while 42.4% is explained by other factors.

3.2 Structural Equation Modelling (SEM)

The latent variables in this study are: risky driving behavior when driving (X1), feeling monotonous when driving (X2), fatigue when driving (X3) and the vigilance when driving (Y). The variables X1, X2, and X3 are independent variables that affect the dependent variable Y, as shown in Figure 4 below. Justification of variable can be seen in Table 3 below:

Table 3. Justification of variable

Indicator	Latent Variables	Source
Coffee consumption (Y.1)	Driver vigilance (Y)	Parkets *et al*, 2001
Driving on curve (Y.2)		Larue *et al*, 2011; Lumba *et al*, 2018
End of journey (Y.3)		
Energy drink consumption (Y.4)		Parkets *et al*, 2001
Road marking (Y.5)		Charlton, 2006
Monotonous road (Y.6)		Ma *et al*, 2003; Thiffault and Bergeron, 2017; Roge *et al*, 2004; Ting *et al*, 2007; Lumba *et al*, 2017; Lumba *et al*, 2018; Schmidt *et al*, 2009
Straight road (Y.7)		Guo *et al*, 2016
Get enough sleep (Y.8)		Lumba *et al*, 2017; Stutts *et al*, 2001; Philip *et al*, 2005; Lumba *et al*, 2017; Roge *et al*, 2004
Age of driver (X1.1)	Risky driving behavior (X1)	Boufous and Williamson, 2009; Sexton *et al*, 2004; Yannis *et al*, 2005; Guo *et al*, 2016;
Engine capacity (X1.2)		Yannis *et al*, 2005;
Driver experience (X1.3)		Liu *et al*, 2018; Shi *et al*, 2010; Patten *et al*, 2006; Sexton *et al*, 2004
Gender of driver (X1.4)		Guo *et al*, 2016; Boufous and Williamson, 2009; Sexton *et al*, 2004
Long duration of driving (X2.1)	Monotonous road (X2)	Ting *et al*, 2007; Lumba *et al*, 2017

Roadside variability (X2.2)		Lumba *et al*, 2018
Traffic volume (X2.3)		Thiffault and Bergeron, 2017
Driving time (X3.1)	Fatigue (X3)	Haworth and Rechnitzer, 1993; Horberry *et al*, 2008
Lack of rest (X3.2)		Lumba *et al*, 2017; Stutts *et al*, 2001; Philip *et al*, 2005; Lumba *et al*, 2017; Roge *et al*, 2004; Ma *et al*, 2003;
Long duration of driving (X3.3)		Ting *et al*, 2007; Lumba *et al*, 2017
Monotonous road (X3.4)		Ma *et al*, 2003; Thiffault and Bergeron, 2017; Roge *et al*, 2004; Ting *et al*, 2007; Lumba *et al*, 2017; Lumba *et al*, 2018; Schmidt *et al*, 2009
Work routines (X3.5)		Hensher et al, 1992
Work schedules (X3.6)		Hensher et al, 1992
Types of work (X3.7)		Hensher et al, 1992

The results of SEM analysis, P value are from each formative indicator as shown in Table 4. Based on Table 4 above, it is obtained indicator variables that significantly influence latent variables that can be seen in Table 5.

Table 4. P value of indicator formatif

***Latent* Variables**	**Indicator**	**P Value**
Driver vigilance (Y)	Coffee consumption (Y.1)	0.394 > 0.05
	Driving on curve (Y.2)	0.051 > 0.05
	End of journey (Y.3)	0.15 > 0.05
	Energy drink consumption (Y.4)	0.340 > 0.05
	Road marking (Y.5)	0.019 < 0.05
	Monotonous road (Y.6)	0.025 < 0.05
	Straight road (Y.7)	0.088 > 0.05
	Get enough sleep (Y.8)	0.000 < 0.05
Risky driving behavior (X1)	Age of driver (X1.1)	0.002 < 0.05
	Engine capacity (X1.2)	0.000 < 0.05
	Driver experience (X1.3)	0.001 < 0.05
	Gender of driver (X1.4)	0.120 > 0.05
Monotonous road (X2)	Long duration of driving (X2.1)	0.001 < 0.05
	Roadside variability (X2.2)	0.482 > 0.05
	Traffic volume (X2.3)	0.258 > 0.05
Fatigue (X3)	Driving time (X3.1)	0.097 > 0.05
	Lack of rest (X3.2)	0.000 < 0.05
	Long duration of driving (X3.3)	0.409 > 0.05
	Monotonous road (X3.4)	0.210 > 0.05
	Work routines (X3.5)	0.298 > 0.05
	Work schedules (X3.6)	0.408 > 0.05
	Types of work (X3.7)	0.139 > 0.05

Table 5. Indicator formative that affect latent variables

***Latent* Variables**	**Indicator**	**P Value**
Driver vigilance (Y)	Road marking (Y.5)	0.019 < 0.05
	Monotonous road (Y.6)	0.025 < 0.05
	Get enough sleep (Y.8)	0.000 < 0.05
Risky driving behavior (X1)	Age of driver (X1.1)	0.002 < 0.05
	Engine capacity (X1.2)	0.000 < 0.05
	Driver experience (X1.3)	0.001 < 0.05
Monotonous road (X2)	Long duration of driving (X2.1)	0.001 < 0.05
Fatigue (X3)	Lack of rest (X3.2)	0.000 < 0.05

Based on Table 5 above, the latent variable vigilance (Y) can be measured by several formative indicators including: road marking (Y5), monotonous road (Y6) and get enough sleep (Y8). It shows that road marking, monotonous road, and get enough sleep can affect the vigilance of motor vehicle driver when driving.

The latent variable risky driving behavior (X1) can be measured by several formative indicators including: age of driver (X1.1), Engine capacity (X1.2) and driver experience (X1.3). It shows that age of driver, engine capacity and driver experience can influence risky driving behavior. Latent variable monotonous road (X2) can be measured by a formative indicator long duration of driving (X2.1). It shows that long duration of driving can affect monotonous drivers. The latent variable fatigue (X3) can be measured by the formative indicator of lack of rest (X3.2). It shows that the lack of rest can affect the level of driver fatigue.

Table 6. Path coefficient

	X3	**Y**	**X2**	**X1**	**P Value**
X3		0,579			0.000
Y					
X2		-0,033			0,396
X1		0,391			0,000

Based on Table 6 above is obtained equation: Y=0,391X1 + 0,579X3 + 0,247, and R square = 0,753. The latent variable feeling monotonous when driving (X2) does not effect on the driver's latent variable vigilance (Y). Meanwhile, the value of R square model = 0.753 indicates that the latent variable risky driving behavior when driving (X1), and the latent variable fatigue when driving (X3) can explain the latent variable vigilance (Y) by 75.3%, while 24.7% is explained by other factors. The more risky the driver's behavior and the more tired the driver, it will more likely to cause decrement in the driver's alertness.

4. CONCLUSION

Regression analysis shows that latent variable the : risky driving behavior when driving (X1), latent variable feeling monotonous when driving (X2) and latent variable fatigue when driving (X3) can explain vigilance (Y) variable by 57.6%, while 42.4% is explained by other factors. SEM analysis, latent variable risky driving behavior when driving (X1), and the latent variable fatigue when driving (X3) can explain the latent variable vigilance (Y) by 75.3%, while 24.7% is explained by other factors. The difference value of R square between regression analysis and SEM analysis are caused by: 1) The multi-collinearity is not allowed in regression analysis, while it is allowed in the SEM analysis; 2) there is no latent variable in the regression analysis, while there are latent

variables and and indicators in the SEM analysis; 3) the regression analysis is explanatory, while the SEM analysis is confirmatory. The regression analysis the monotonous condition affects the vigilance of the driver, but in the SEM analysis, the monotonous condition does not affect the vigilance of the driver.

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