CIVIL & ENVIRONMENTAL ENGINEERING | CIVIL & ENVIRONMENTAL ENGINEERING

Prohibitory traffic signs violation by well-educated young drivers based on situation scenarios

Bambang Suhardi¹,¹, Farid Ishartomo² and Jafri Mohd Rohani²

Abstract: Traffic violations in Indonesia were mostly committed by young drivers. Surprisingly, university students ranked third as traffic violators despite they are expected to have better understanding of traffic signs instead of others. This study was conducted to investigate the influence factors that might encourage university students as well-educated young drivers to commit traffic violations through several situation scenarios. Five prohibitory traffic signs (no u-turn, no parking, stop sign, maximum speed limit, no stopping) were subjectively evaluated by 212 university students (18–23 years old, having valid car and or motorcycle driving license) whether they will violate these signs in 7 situation scenarios as indicators based on human-related factors (no police officers, in a hurry, imitate mistakes, sleep deprivation and fatigue) and environmental-related factors (quiet roads, night driving, driving in heavy rain). From the results, the influence varied for each sign. Both factors influenced no u-turn, no parking and no stopping signs. Human-related factors influenced maximum speed limit sign while environmental-related factors influenced stop sign. This study has provided a useful initial insight to understand young driver’s behavior to violate these prohibitory traffic signs. For further studies, it can be applied to other signs with different respondent profiles. Apart from that, the relationship between indicators can also be investigated.

Keywords: Traffic signs; sign violation; young drivers

Subjects: Industrial Engineering & Manufacturing

1. Introduction

Based on Land Transportation Statistics 2019 released by the Central Bureau of Statistics of the Republic of Indonesia (2019), there were 116,411 traffic accidents with 25,671 people deaths, 12,475 seriously injured and 137,342 minor injuries. The number of accidents in Indonesia since 2015–2019 has been annually increased by 4.87%. However, the large number of accidents in Indonesia is also related to the large number of private motorized vehicles and the drivers based on driving license ownership. In 2019, there were 15,592,419 passenger cars and 112,771,136 motorcycles in Indonesia, as well as 4,139,101 drivers who have passenger cars driving license and 9,304,877 drivers who have motorcycles driving license. The number of passenger cars and motorcycles in Indonesia since 2015–2019 has been annually increased by 6.10% and 6.20% respectively.

Drivers are one of the important factors on road safety performance (Arowolo et al., 2014). The Indonesian National Police (2013) stated that drivers who were not orderly traffic rules are a major factor of road accidents in Indonesia, whereas traffic rules are designed to regulate the traffic behavior of road users. Traffic signs are one of the traffic regulation instruments. Comprehension
of traffic signs may consider human characteristics of the drivers, ergonomic principles, cognitive features and the cultural issues (Ishartomo et al., 2020). Familiarity with signs can help drivers understand their meaning (Abduljabbar et al., 2020), but familiarity is not always linear with comprehensibility. Drivers who are familiar with certain signs do not always understand their meaning (Akpie et al., 2020).

Based on current regulation in Indonesia by Ministry of Transportation (2014) Article 1 and Article 3, traffic signs are defined as part of road equipment in the form of symbols, letters, numbers, sentences, and or combination that functions as warnings, prohibitions, orders, or instructions for road users. Traffic signs based on their type consist of: (a) warning signs; (b) prohibitory signs; (c) command signs; and (d) information signs. Compared to other type of signs, it was previously known that drivers were able to react more quickly in understanding prohibitory traffic signs (Castro et al., 2012). Article 11 of the regulation (Ministry of Transportation of the Republic of Indonesia, 2014) also explained that prohibitory traffic signs are used to state actions that are prohibited from being carried out by road users. It consist of: (a) prohibition to continues, (b) entry prohibition, (c) parking restrictions and stopping, (d) prohibition of certain traffic movements, (e) prohibition against sounding signals, (f) prohibition with words, and (g) the end of the prohibition signs.

Traffic violations in Indonesia were mostly committed by young drivers in the age of 16–21 years old (Indonesia National Police, 2013). In that age range, mostly young drivers were high schools students and university students. The data from Indonesia National Police (2013) also showed that high schools students and university students ranked first and third as traffic violators. This may come as a bit of a surprise since young drivers studying at the universities are expected to have better understanding of traffic signs (Ghadban et al., 2018). Young drivers with undergraduate background defined as well-educated young drivers because they are considered to have better knowledge of traffic signs than others. In the end, well-educated young drivers as part of a smart society are expected to be an important part of the creation of a smart city (Habeeb & Weli, 2020).

The violation of traffic signs by drivers is an interesting subject to be learned and investigated. It was known by several researchers that traffic signs can influence driver’s decision-making behaviors (Vilchez, 2019) and performances (Sandu, 2013) or even a tool for behavioral changes (Meis et al., 2017). Moreover, combination and adjustment of road signs, context and laws can make the drivers avoid ambiguous situations and doubtful decision-making, and then automatically subject the drivers to compliance with applicable laws (Bazire & Tijus, 2009). Violations of traffic signs occurs because of the human errors in understanding the meaning of signs, indifference to signs and the weakness supervision and enforcement of traffic laws (Winarso, 2016). A combination of poor traffic rules knowledge, a tendency to speed, an inability to control emotions and focus on driving can lead to someone violating traffic rules (Lady et al., 2020). Meanwhile, Agustin (2019) identified 3 causes of traffic rule violations, namely: driver’s knowledge, intensity of raid operations and intensity of law enforcement.

In the previous study based on subjective interview to local Indonesian drivers about the behavior of road users (Winarso, 2016), it can be concluded that the violation and ignorance of the traffic signs, road markings, and traffic signal devices were stimulated by internal, external and other factors. The internal factor described as the needs to get to the destination as soon as possible. Meanwhile, the external factors described as stimulation of the situation, e.g., the probability to get trapped in a traffic jam and the poor law enforcement by police officers. The other factors described as pressure from environment, such as faded or blurred traffic signs. Poor law enforcement could be due to a lack of traffic police personnel on duty. This kind of situation sometimes provides an opportunity for drivers to break traffic rules. In addition, the lack of police officers can cause violations to be carried out without fines, so that other drivers felt that it was not a wrong attitude and followed by other drivers (Purnamasari, 2019; Purnamasari & Ansusanto, 2017). The vehicle-following behavior had been analyzed recently (Fulu et al., 2020). In fact, people actually want the implementation of fines and
sanctions against traffic violators to be applied equally based on their mistakes (Agustin, 2019; Purnamasari, 2019; Purnamasari & Ansusanto, 2017).

An investigation of road users' situation awareness in different road environments such as wet, slippery, debris, quiet and busy roads found that it can influence driver's awareness (Salmon et al., 2014). In addition, Imran et al. (2021) observed that traffic flow characterization and driver reaction were related. Another opinion stated that a tired or fatigue driver has its potential to ignore traffic rules (Ho et al., 2015; Ho & Widaningrum, 2016). Sleep related driving fatigue experiment has been previously investigated (Sanjaya et al., 2018). In sleep-deprived condition, the young driver's visual attention was decreased compared to drivers who have 8-hours normal sleep and can affect their driving performance (Wijayanto et al., 2018). Meanwhile, insufficient lighting at night can increase the risk of traffic violations and accidents (Setyaningsih et al., 2018). Driving in heavy rain is also quite dangerous due to reduced visibility of the drivers. The worsening weather conditions, such as heavy rain, etc., have significant effect on increasing drivers' perceived risk due to limited visibility (Chen et al., 2019). This is in line with research related to situation awareness in different road environments (Salmon et al., 2014). However, signs related to environmental condition are needed to warn road users (Ben-Bassat, 2019).

From several previous studies, the causal factors (Winarso, 2016) can be simplified into 2 factors: human-related factors and environmental-related factors. It also related to Iqbal et al. (2020) who identified human errors and environmental factors as the contributing factors in road traffic accidents. Several situation scenarios that may affect driver's intention to violate traffic signs can also be added as shown in Table 1. Human-related factors can be specified into four aspects, that is, “No Police Officers” (Purnamasari, 2019; Purnamasari & Ansusanto, 2017; Winarso, 2016), “In A Hurry” (Purnamasari, 2019; Purnamasari & Ansusanto, 2017; Winarso, 2016), “Imitate Mistakes” (Purnamasari, 2019; Purnamasari & Ansusanto, 2017; Winarso, 2016) and “Sleep Deprivation & Fatigue” (Ho et al., 2015; Ho & Widaningrum, 2016; Sanjaya et al., 2018; Wijayanto et al., 2018) while environmental-related factors can be specified into 3 aspects, that is, “Quiet Roads” (Salmon et al., 2014), “Night Driving” (Setyaningsih et al., 2018) and “Driving in Heavy Rain” (Chen et al., 2019; Salmon et al., 2014). This study analyzed the influence factors of traffic signs violation based on several situation scenarios by well-educated young drivers in Indonesia. This is important for stakeholders so that in the future preventive measures can be taken to reduce the number of traffic violations and traffic accidents among adolescents.

| Table 1. Traffic signs violation based on situation scenarios |
|-------------------------------------------------------------|
| **Factors** | **Situation scenarios** | **References** |
|-----------------|----------------------|----------------|
| Human-related factors | No police officers | Winarso (2016); Purnamasari and Ansusanto (2017); Purnamasari (2019) |
| | In a hurry | Winarso (2016); Purnamasari and Ansusanto (2017); Purnamasari (2019) |
| | Imitate mistakes | Winarso (2016); Purnamasari and Ansusanto (2017); Purnamasari (2019) |
| | Sleep deprivation & fatigue | Ho et al. (2015); Ho and Widaningrum (2016); Sanjaya et al. (2018); Wijayanto et al. (2018) |
| Environmental-related factors | Quiet roads | Salmon et al. (2014) |
| | Night driving | Setyaningsih et al. (2018) |
| | Driving in heavy rain | Salmon et al. (2014); Chen et al. (2019) |
2. Methods

2.1. Research design
This study focused on five prohibitory traffic signs in Indonesia as sample signs, that is, “No U-Turn”, “No Parking”, “Stop Sign”, “Maximum Speed Limit” and “No Stopping”, as it shown in Figure 1. These five signs were selected based on a study conducted by Purnamasari (2019). All of them have comprehensibility level above 83%, so it is expected that all drivers will not experience difficulties in understanding the meaning of these signs. The signs were coded as Sign 1 to Sign 5 respectively.

The research design is shown in Figure 2 below. Human-related factors and environmental-related factors were considered in sign violation. The human-related factors are no police officers, in a hurry, imitate mistakes and sleep deprivation & fatigue. The environmental-related factors are quiet roads, night driving and driving in heavy rain. Data variables are shown in Table 2. Sign Violation (YVIO) as dependent variable consists of two dimensions as independent variables that is, human-related factors (X3HUM) and Environmental-related factors (X4ENV). Human-related factors (X3HUM) consist of four items as indicator variables: No Police Officers (VPO), In a Hurry (VIH), Imitate Mistakes (VIM), and Sleep Deprivation and Fatigue (VSF). Environmental-related factors (X4ENV) consist of three items as indicator variables: Quiet Roads (VQT), Night Driving (VND), and Driving in Heavy Rain (VHR).

2.2. Data collection
The questionnaire survey method was used for data collection. It was developed using Google Forms and distributed online from 22 September to 21 October 2020 via Twitter as social media platform to undergraduate students of Universitas Sebelas Maret (UNS) in Surakarta, Indonesia with the age between 18 and 23 years old and owned a personal driving license to drive passenger cars and/or motorcycles. Newly undergraduate students in Indonesia generally started from 18 years old and graduated at the age of 23 years old (Ministry of Research, Technology and Higher Education of the Republic of Indonesia, 2018). Other than that, the requirement for an individual driving license applicant to drive cars or motorcycles is at least 17 years old based on Article 81 Law number 22 Year 2009 (Government of the Republic of Indonesia, 2009). The
questionnaire was divided into two parts. In Part I, respondents were asked about their personal characteristics, that is, age, gender, educational background and type of driving license. In Part II, respondents were asked to conduct a subjective evaluation of these signs through seven statements as it shown in Table 3 by choosing one of the five available answer options, that is, Strongly Agree, Agree, Neutral, Disagree and Strongly Disagree. There was no question about the meaning of the signs so that all respondents were considered to know the meaning of the signs being tested.

As many as 212 undergraduate students were willing to participate in this survey. All respondents were considered to have no color blindness problem. Personal characteristics of the respondents are shown in Table 4. The respondents were mostly 21 years old (52 students; 24.53%). Female students were more participated (162 students; 76.42%) than male students (50 students; 23.58%). The respondents consisted of 149 bachelor students (70.28%) and 63 diploma students (29.72%). Most of the respondents had motorcycle driving license (159 students; 75.00%) and the rest had both type of car and motorcycle driving license (53 students; 25.00%). The frequency distribution of human-related factors and environmental-related factors from respondents’ answers are shown in Tables 5 and Tables 6 respectively.

2.3. Data analysis
Partial Least Squares–Structural Equation Modeling (PLS-SEM) method was chosen to analyze the data since PLS-SEM can be used to develop an exploratory model (Garson, 2016). SmartPLS 3.2.8 Professional trial version software was used as a tool to do PLS analysis. The PLS analysis theoretical framework was shown in Figure 3. Variable YVIO (Sign Violation) as latent variable

| Table 2. Data variables                                                                 | Independent variables (manifest) | Indicators (items)               |
|----------------------------------------------------------------------------------------|----------------------------------|----------------------------------|
| Dependent variable (latent)                                                           | Human-related factors (X3HUM)     | No police officers (YPO)         |
|                                                                                        |                                  | In a hurry (YIH)                 |
|                                                                                        |                                  | Imitate mistakes (YIM)           |
|                                                                                        |                                  | Sleep deprivation & fatigue (YVF) |
|                                                                                        | Environmental-related factors (X4ENV) | Quiet roads (YQT)               |
|                                                                                        |                                  | Night driving (YND)              |
|                                                                                        |                                  | Driving in heavy rain (YHR)      |

| Table 3. Questionnaire statements                                                      | Indicators                        | Statements                                      |
|----------------------------------------------------------------------------------------|-----------------------------------|-------------------------------------------------|
| 1                                                                                      | No police officers                | I will violate this sign if there are no police officers in charge. |
| 2                                                                                      | In a hurry                        | I will violate this sign if I am in a hurry.    |
| 3                                                                                      | Imitate mistakes                  | I will violate this sign if others also violate it. |
| 4                                                                                      | Sleep deprivation & fatigue       | I will violate this sign if I feel sleep deprived and fatigue. |
| 5                                                                                      | Quiet roads                       | I will violate this sign if I drive in quiet roads. |
| 6                                                                                      | Night driving                     | I will violate this sign if I drive at night and it is dark. |
| 7                                                                                      | Driving in heavy rain             | I will violate this sign if I drive in heavy rain. |
consisted of two dimensions, that is, X3HUM (Human-related factors), and X4ENV (Environmental-related factors). Dimension X3HUM consisted of four indicators as manifest variables: VPO (No Police Officers), VIH (In a Hurry), VIM (Imitate Mistakes), and VSF (Sleep Deprivation and Fatigue). Dimension X4ENV consisted of three indicators as manifest variables: VQT (Quiet Roads), VND (Night Driving), and VHR (Driving in Heavy Rain).

Two stages of evaluation have been done for each signal, that is, measurement model (outer model) and structural model (inner model). Since it was a formative relation, evaluation were done by checking convergent validity (outer loadings >0.7), co-linearity statistics (VIF < 5), outer weights (T statistics > 1.96; p value < 0.05) and path coefficients (p value < 0.05). After running the PLS algorithm in SmartPLS software, the outer loadings and VIF have to be checked. If the outer loadings are less than 0.7 and the VIF are more than 5, then the indicators have to be deleted and repeated the model running (Garson, 2016). If the outer loadings and VIF of each sign is all valid, the model can be calculated using Bootstrapping with the significance level of 0.05 (α = 5%) to check the outer weights and path coefficients.

3. Results and discussion
The results of this study explained for each sign in detail, that is, Sign 1 (No U-Turn), Sign 2 (No Parking), Sign 3 (Stop Sign), Sign 4 (Maximum Speed Limit), and Sign 5 (No Stopping).

3.1. Sign 1 (No U-Turn)
The final path diagram of Sign 1 is shown in Figure 4 while the outer weights and path coefficients are shown in Table 7. From the outer weights in Table 7, No Police Officers (VPO), Imitate Mistakes (VIM), Sleep Deprivation & Fatigue (VSF) were good indicators (T statistics > 1.96; p value < 0.05) for human-related factors (X3HUM) and also good direct indicators for sign violation (YVIO), while In a Hurry (VIH) was not a good indicator (T statistics 0.076 < 1.96; p value 0.939 > 0.05) for human-related factors (X3HUM) and also not a good direct indicator (T statistics 0.075 < 1.96; p value 0.940 > 0.05) for sign violation (YVIO). Quiet Roads (VQT), Night Driving (VND) and Driving in Heavy Rain (VHR) were good indicators (T statistics > 1.96; p value < 0.05) for environmental-related factors (X3HUM) and also good direct indicators for sign violation (YVIO). From the path coefficients in Table 7, both of human-related factors (X3HUM) and environmental-related factors (X4ENV) had positive influence and significant (p value < 0.05) to sign violation (YVIO).
Both of human-related factors (no police officers, imitate mistakes, sleep deprivation & fatigue) and environmental-related factors (quiet roads, night driving, driving in heavy rain) had positive influence and significant to “No U-turn” sign violation. It means that students have intention to violate it if there are no police officers, if other drivers also violate it, if they feel sleepy and tired, if the road is quiet, if they drive at night and also if they drive in a heavy rain. It is a serious problem that stakeholders must give attention to this matter since 6 out of 7 situation scenarios were had positive influence. There is only in a hurry situation that did not give positive influence. However, this does not guarantee that drivers in a hurry will not violate this sign. Purnamasari and Ansusanto (2017) and Purnamasari (2019) argued that in a hurry situation was the second major factor after no police officers situation that might encourage drivers to violate signs. Even though they want to get to the destination quickly, students might also need other situations to strengthen their intention to violate this sign.

| Indicators                        | Answers          | Sign 1 | Sign 2 | Sign 3 | Sign 4 | Sign 5 |
|-----------------------------------|------------------|--------|--------|--------|--------|--------|
| No police officers                | Strongly Disagree| 80     | 79     | 58     | 37     | 66     |
|                                  | Disagree         | 66     | 53     | 62     | 35     | 54     |
|                                  | Neutral          | 37     | 55     | 43     | 59     | 58     |
|                                  | Agree            | 20     | 18     | 16     | 55     | 19     |
|                                  | Strongly Agree   | 9      | 7      | 6      | 26     | 15     |
| Total                             |                  | 212    | 212    | 212    | 212    | 212    |
| In a hurry                        | Strongly Disagree| 77     | 72     | 79     | 33     | 57     |
|                                  | Disagree         | 48     | 72     | 67     | 30     | 61     |
|                                  | Neutral          | 43     | 40     | 41     | 53     | 59     |
|                                  | Agree            | 30     | 23     | 17     | 59     | 22     |
|                                  | Strongly Agree   | 14     | 5      | 8      | 37     | 13     |
| Total                             |                  | 212    | 212    | 212    | 212    | 212    |
| Imitate mistakes                  | Strongly Disagree| 86     | 81     | 88     | 42     | 71     |
|                                  | Disagree         | 56     | 50     | 60     | 43     | 62     |
|                                  | Neutral          | 32     | 43     | 50     | 64     | 49     |
|                                  | Agree            | 24     | 35     | 11     | 35     | 21     |
|                                  | Strongly Agree   | 14     | 3      | 3      | 28     | 9      |
| Total                             |                  | 212    | 212    | 212    | 212    | 212    |
| Sleep deprivation & fatigue       | Strongly Disagree| 100    | 86     | 91     | 50     | 73     |
|                                  | Disagree         | 63     | 71     | 65     | 46     | 70     |
|                                  | Neutral          | 31     | 35     | 41     | 58     | 46     |
|                                  | Agree            | 14     | 15     | 12     | 33     | 18     |
|                                  | Strongly Agree   | 4      | 5      | 3      | 25     | 5      |
| Total                             |                  | 212    | 212    | 212    | 212    | 212    |
3.2. Sign 2 (No parking)

The final path diagram of Sign 2 is shown in Figure 5 while the outer weights and path coefficients are shown in Table 8. From the outer weights in Table 8, In a Hurry (VIH), Imitate Mistakes (VIM) and Sleep Deprivation & Fatigue (VSF) were good indicators (T statistics > 1.96; p value < 0.05) for human-related factors (X3HUM) and also good direct indicators for sign violation (YVIO), while No Police Officers (VPO) was not a good indicator (T statistics 1.911 < 1.96; p value 0.057 > 0.05) for human-related factors (X3HUM) and also not a good direct indicator (T statistics 1.936 < 1.96; p value 0.054 > 0.05) for sign violation (YVIO). Quiet Roads (VQT), Night Driving (VND) and Driving in heavy rain (VHR) were not good indicators for human-related factors (X3HUM) and sign violation (YVIO). Table 6 shows the frequency distribution of environmental-related factors (n = 212).

Table 6. Frequency distribution of environmental-related factors (n = 212)

| Indicators               | Answers          | Sign 1 | Sign 2 | Sign 3 | Sign 4 | Sign 5 |
|-------------------------|------------------|--------|--------|--------|--------|--------|
| Quiet roads             | Strongly Disagree| 78     | 79     | 79     | 34     | 67     |
|                         | Disagree         | 56     | 67     | 61     | 39     | 58     |
|                         | Neutral          | 36     | 35     | 47     | 55     | 56     |
|                         | Agree            | 25     | 23     | 18     | 43     | 19     |
|                         | Strongly Agree   | 17     | 8      | 7      | 41     | 12     |
| Total                   |                  | 212    | 212    | 212    | 212    | 212    |
| Night driving           | Strongly Disagree| 81     | 78     | 83     | 36     | 70     |
|                         | Disagree         | 61     | 64     | 68     | 45     | 64     |
|                         | Neutral          | 27     | 38     | 43     | 58     | 45     |
|                         | Agree            | 25     | 21     | 10     | 39     | 18     |
|                         | Strongly Agree   | 17     | 11     | 8      | 34     | 15     |
| Total                   |                  | 212    | 212    | 212    | 212    | 212    |
| Driving in heavy rain   | Strongly Disagree| 93     | 84     | 87     | 49     | 70     |
|                         | Disagree         | 73     | 59     | 68     | 54     | 66     |
|                         | Neutral          | 26     | 39     | 42     | 63     | 45     |
|                         | Agree            | 13     | 23     | 11     | 25     | 19     |
|                         | Strongly Agree   | 7      | 7      | 4      | 21     | 12     |
| Total                   |                  | 212    | 212    | 212    | 212    | 212    |

Figure 3. PLS analysis theoretical framework.
Heavy Rain (VHR) were good indicators (T statistics > 1.96; p value < 0.05) for environmental-related factors (X3HUM) and also good direct indicators for sign violation (YVIO). From the path coefficients in Table 8, both of human-related factors (X3HUM) and environmental-related factors (X4ENV) had positive influence and significant (p value < 0.05) to sign violation (YVIO).

Both of human-related factors (in a hurry, imitate mistakes, sleep deprivation and fatigue) and environmental-related factors (quiet roads, night driving, driving in heavy rain) had positive influence and significant to “No Parking” sign violation. It means that students will violate “No Parking” sign if they are in a hurry, if they know that other drivers did it, if they are tired and sleep deprived, if the road is quiet, if they drive their vehicles at night and also if they drive in a heavy rain. The absence of police officers did not influence the students to violate it. This sign is closely related to the availability of parking spaces that are not only on the roadside but also in certain places, e.g., mall, office, universities, etc., where the police officers are rarely seen.

3.3. Sign 3 (Stop sign)
The final path diagram of Sign 3 is shown in Figure 6 while the outer weights and path coefficients are shown in Table 9. From the outer weights in Table 9, No Police Officers (VPO), Imitate Mistakes (VIM) and Sleep Deprivation & Fatigue (VSF) were good indicators (T statistics > 1.96; p value <
0.05) for Human-related factors (X3HUM) but In a Hurry (VIH) was not a good indicator (T statistics $1.906 < 1.96$; $p$ value $0.058 > 0.05$) for Human-related factors (X3HUM). All of No Police Officers (VPO), In a Hurry (VIH) and Sleep Deprivation & Fatigue (VSF) were not good direct indicators (T statistics $< 1.96$; $p$ value $> 0.05$) for sign violation (YVIO), Quiet Roads (VQT), Night Driving (VND) and Driving in Heavy Rain (VHR) were good indicators (T statistics $> 1.96$; $p$ value $< 0.05$) for environmental-related factors (X4ENV) and also good direct indicators for sign violation (YVIO).

From the path coefficients in Table 9, environmental-related factors (X4ENV) had positive influence and significant to sign violation (YVIO) while human-related factors (X3HUM) did not have positive influence and significant (T statistics $0.284 < 1.96$; $p$ value $0.777 > 0.05$) to sign violation (YVIO).

Compared to other factor, only environmental-related factors (quiet roads, night driving, driving in heavy rain) that had positive influence and significant to “Stop” sign violation. It means that

![Final path diagram of Sign 2 (No parking).](image)

| Outer weights and path coefficients | Influence | T-statistics | P-value |
|------------------------------------|-----------|-------------|---------|
| Outer weights
| S2VHR → X4ENV | 4.755 | 0.000       |
| S2VHR1 → YVIO | 4.834 | 0.000       |
| S2VIH → X3HUM | 3.039 | 0.003       |
| S2VIH1 → YVIO | 3.005 | 0.003       |
| S2VIM → X3HUM | 4.149 | 0.000       |
| S2VIM1 → YVIO | 4.113 | 0.000       |
| S2VND → X4ENV | 4.210 | 0.000       |
| S2VND1 → YVIO | 4.424 | 0.000       |
| S2VPO → X3HUM | 1.911 | 0.057       |
| S2VPO1 → YVIO | 1.936 | 0.054       |
| S2VQT → X4ENV | 5.262 | 0.000       |
| S2VQT1 → YVIO | 4.866 | 0.000       |
| S2VSF → X3HUM | 6.115 | 0.000       |
| S2VSF1 → YVIO | 5.358 | 0.000       |
| Path coefficients
| X3HUM → YVIO | 35.800 | 0.000       |
| X4ENV → YVIO | 24.480 | 0.000       |
students will violate this sign if the road is quiet, if they drive their vehicles at night and also if they drive in a heavy rain. This is related to the previous studies that short full text printed on the sign makes it easy for drivers to understand the meaning of the sign and improve its familiarity and comprehensibility (Akple et al., 2020; Ben-Bassat, 2019). Since it has very clear meaning, drivers might only look for environmental-related situations instead of human-related situations to violate this sign.

3.4. Sign 4 (Maximum speed limit)
The final path diagram of Sign 4 is shown in Figure 7 while the outer weights and path coefficients are shown in Table 10. From the outer weights in Table 10, No Police Officers (VPO) and In a Hurry (VIH) were good indicators (T statistics > 1.96; p value < 0.05) for human-related factors (X3HUM) and also good indicators for sign violation (YVIO), while Imitate Mistakes (VIM) and Sleep Deprivation & Fatigue (VSF) were not good indicators for human-related factors (X3HUM). Quiet Roads (VQT) and Night Driving (VND) were good indicators (T statistics > 1.96; p value < 0.05) for environmental-related factors (X4ENV) while Driving in Heavy Rain (VHR) was not a good indicator (T statistics 1.557 < 1.96; p value 0.121 > 0.05) for environmental-related factors (X4ENV). From the path coefficients in Table 10, human-related factors (X3HUM) had positive influence and significant

![Final path diagram of Sign 3 (Stop sign)](image)

| Outer weights and path coefficients | Influence | T-statistics | P-value |
|------------------------------------|-----------|-------------|---------|
| Outer weights                      | S3VHR → X4ENV | 3.443 | 0.001 |
|                                    | S3VHR1 → YVIO | 3.433 | 0.001 |
|                                    | S3VH1 → X3HUM | 1.906 | 0.058 |
|                                    | S3VH1 → YVIO | 0.340 | 0.734 |
|                                    | S3VIM → X3HUM | 4.559 | 0.000 |
|                                    | S3VND → X4ENV | 4.461 | 0.000 |
|                                    | S3VND1 → YVIO | 4.460 | 0.000 |
|                                    | S3VPO → X3HUM | 2.403 | 0.017 |
|                                    | S3VPO1 → YVIO | 0.320 | 0.749 |
|                                    | S3VQT → X4ENV | 5.693 | 0.000 |
|                                    | S3VQT1 → YVIO | 5.672 | 0.000 |
|                                    | S3VSF → X3HUM | 4.822 | 0.000 |
|                                    | S3VSF1 → YVIO | 0.274 | 0.785 |
| Path coefficients                  | X3HUM → YVIO | 0.284 | 0.777 |
|                                    | X4ENV → YVIO | 29,060.450 | 0.000 |
(p value < 0.05) to sign violation (YVIO) while environmental-related factors (X4ENV) did not have positive influence and significant to sign violation (YVIO).

There are only human-related factors (no police officers, in a hurry) that had positive influence and significant to “Maximum Speed Limit” sign violation. This means that students will violate this sign if there are no police officers and if they want to get to the destination as soon as possible for several reasons. It is related to previous study by Lady et al. (2020) who stated that speeding behavior can make drivers ignoring traffic rules. Winarto (2016), Purnamasari and Ansusanto (2017), Agustin (2019), and Purnamasari (2019) also concluded that weak supervision and lack of law enforcement became loopholes exploited by traffic rule violators.

3.5. Sign 5 (No stopping)
The final path diagram of Sign 5 is shown in Figure 8. After the outer loadings and VIF of Sign 5 were all valid, the model can be calculated using Bootstrapping mode to check the outer weights and path coefficients as shown in Table 11. From the outer weights in Table 11, In a Hurry (VIH), Imitate Mistakes (VIM) and Sleep Deprivation & Fatigue (VSF) were good indicators (T statistics > 1.96; p value < 0.05) for human-related factors (X3HUM) and also good indicators for sign violation (YVIO), while No Police Officers (VPO) were not a good indicator (T statistics 1.326 < 1.96; 0.186 > 0.05) for human-related factors (X3HUM) and also not a good indicator (T statistics 1.338 < 1.96; 0.182 > 0.05) for sign violation (YVIO). Quiet Roads (VQT), Night Driving (VND) and Driving in Heavy Rain (VHR) were good indicators (T statistics > 1.96; p value < 0.05) for environmental-related factors (X4ENV) and also good direct indicators for sign violation (YVIO). From the path coefficients in Table 11, both of human-related factors (X3HUM) and environmental-related factors (X4ENV) had positive influence and significant (p value < 0.05) to sign violation (YVIO).
Both of human-related factors (in a hurry, imitate mistakes, sleep deprivation and fatigue) and environmental-related factors (quiet roads, night driving, driving in heavy rain) had positive influence and significant to “No Stopping” sign violation. This means that students will violate this sign if they are in a hurry, if other drivers violate it, if they feel sleep deprived and tired, if the road is quiet, if they drive at night and also if they drive in a heavy rain. The fact that this sign has similar design with the Sign 2 (No Parking) which used single letter is quite interesting since both gave similar results, as it shown in Table 12. According to Purnamasari (2019), both also had high percentages of comprehensibility level above 90%. The absence of police officers is not a sufficient reason to violate this sign that might be because drivers felt that the enforcement of violation is lenient in Indonesia so community actually wants law enforcement against violations of traffic rules in a fair and transparent manner (Purnamasari & Ansusanto, 2017). However, having the police officers on duty might discourage young drivers from violating this sign, even though other situations are very favorable for doing so.

4. Conclusion
This study showed that the human-related factors and environmental-related factors influenced well-educated young drivers’ intention to violate these five prohibitory traffic signs. Nevertheless, the influence indicators varied for each sign, as it shown in Table 12. For signs that contained a full
symbol, for example, “No U-Turn”, and a single letter, for example, “No Parking” and “No Stopping”, both factors influenced driver’s intention to violate it. Meanwhile, for a sign that contained a full text, for example, “Stop Sign”, environmental-related factors are more influenced the driver’s intention to violate it. In the other hand, human-related factors are more influenced young drivers to violate a sign that contained numbers and letters, for example, “Maximum Speed Limit”.

This study was limited to five prohibitory traffic signs with seven situation scenarios only. It should be applied to other signs in further studies. The relationship between situation scenarios is also interesting to analyze. Each situation might influence each other. Since this study only focused on young drivers who study at the university, it is necessary to compare with respondents from different groups. In addition, the coverage of respondents can be expanded to obtain results that can reflect the actual conditions. However, this study has provided a useful initial insight to understand young driver’s behaviors to violate these prohibitory traffic signs. In the future, improvements can be made which are deemed necessary in order to reduce signs violation and traffic accidents.

### Table 12. Influence analysis of sign violation

| Dimensions         | Indicators                          | Sign 1 | Sign 2 | Sign 3 | Sign 4 | Sign 5 |
|--------------------|-------------------------------------|--------|--------|--------|--------|--------|
| Human-related factors | No police officers                  | 𓅀     | 𓅀     | 𓅀     | 𓅀     | 𓅀     |
|                    | In a hurry                          | 𓅀     | 𓅀     | 𓅀     | 𓅀     | 𓅀     |
|                    | Imitate mistakes                    | 𓅀     | 𓅀     | 𓅀     | 𓅀     | 𓅀     |
|                    | Sleep deprivation & fatigue         | 𓅀     | 𓅀     | 𓅀     | 𓅀     | 𓅀     |
| Environmental-related factors | Quiet roads                       | 𓅀     | 𓅀     | 𓅀     | 𓅀     | 𓅀     |
|                    | Night driving                       | 𓅀     | 𓅀     | 𓅀     | 𓅀     | 𓅀     |
|                    | Driving in heavy rain               | 𓅀     | 𓅀     | 𓅀     | 𓅀     | 𓅀     |

### Funding

The authors received no direct funding for this research.

### Author details

Bambang Suhardi
E-mail: bambangsuhardi@staff.uns.ac.id
ORCID ID: http://orcid.org/0000-0001-7700-3494

Marinella Giunta
Reviewing editor

### Disclosure statement

No potential conflict of interest was reported by the author(s).

### Citation information

Cite this article as:

Cite this article as: Prohibitory traffic signs violation by well-educated young drivers based on situation scenarios, Bambang Suhardi, Farid Ishartomo & Jafri Mohd Rohani, Cogent Engineering (2021), 8: 1981519.

### References

Abduljabbar, A. S., Jaleel, Z. T., & Salman, N. D. (2020). Traffic signs comprehension study. IOP conference series: Materials science and engineering, 737, 012143 1–9. IOP Publishing. https://doi.org/10.1088/3757-899X/737/1/012143

Agustin, I. W. (2010). Traffic violation are mostly carried out by motorcyclist. AIP conference proceedings, 2202, 020118 1–9. Surakarta, Indonesia. https://doi.org/10.1063/1.5141731

Akple, M. S., Sogbe, E., & Atombo, C. (2020). Evaluation of road traffic signs, markings and traffic rules compliance among drivers in Ghana. Case Studies on Transport Policy, 8(4), 1295–1306. https://doi.org/10.1016/j.ctsp.2020.09.001

Arowolo, M. O., Rohani, J. M., & Rani, M. R. A. (2014). Development of road safety sustainability model for Malaysian road. Applied Mechanics and Materials, 606, 235–239. https://doi.org/10.4028/www.sciencedirect.com/AMM.606.235

Bazire, M., & Tijus, C. (2009). Understanding road signs. Safety Science, 47(9), 1232–1240. https://doi.org/10.1016/j.ssci.2009.03.013

Ben-Bassat, T. (2019). Are ergonomically designed road signs more easily learned? Applied Ergonomics, 78, 137–147. https://doi.org/10.1016/j.apergo.2019.02.009

Castro, C., Moreno-Rios, S., & Tornay, F. J. (2012). Cognitive representations of obligation and prohibition signs when they provide the same amount of semantic information. Psicología, 33, 275–291. https://www.uv.es/reviews/articulos2.126/6CASTRO.pdf
Central Bureau of Statistics of the Republic of Indonesia. (2019). Land transportation statistics 2019. Jakarta BPS-Statistics Indonesia. https://www.bps.go.id/publikation/2020/11/20/doc/34c9253677/f07065dosta
istik-transportasi-darat-2019.html

Chen, C., Zhao, X., Liu, H., Ren, G., & Liu, X. (2019). Influence of adverse weather on driver's perceived risk during car following based on driving simulations. Journal of Modern Transportation, 27(4), 282–292. https://doi.org/10.1007/s40534-019-00197-6

Fulu, W., Long, C., Yongqing, G., Mingtao, C., & Jixiang, M. (2020). Car-following behavior analysis of left-turn vehicles at signalized intersections. Civil Engineering Journal, 6(1), 186–193. https://doi.org/10.28991/cej-2020-030910

Garson, G. D. (2016). Partial least squares: regression & structural equation models. Statistical Associates Publishing. https://www.smartpls.com/resources/ebook_on pls-sem pdf

Ghadbani, N. R., Abdella, G. M., Alhajyaseen, W., & Al-Khalifa, K. N. (2018). Analyzing the impact of human characteristics on the comprehensibility of road traffic signs. The 2018 International conference on industrial engineering and operation management (EOM), ICOM, Bandung, Indonesia.

Government of the Republic of Indonesia. (2009). Law No. 22 Year 2009 of traffic and road transport. In. Indonesian. Republic of Indonesia https://jihd.dephub.go.id/assets/udocs/uu/lu_no.22_tahun_2009 pdf

Habeeb, N. J., & Wei, S. T. (2020). Relationship of smart cities and smart tourism: An overview. HighTech and Innovation Journal, 1(4), 194–202. https://doi.org/10.28991/HIJ-2020-01-04-07

Ho, H. C., Leona, D., Suhartono, I. S., & Reynolds, M. (2015). Pursuing the quality of driving through an understanding of job security, job satisfaction, and perceived safety as antecedents of motorcycling behaviors in Jakarta, Indonesia. The 2015 International conference on industrial engineering and operation management (EOM), ICOM, Dubai, United Arab Emirates. https://doi.org/10.1109/IEEE.2015.7981797

Ho, H. C., & Widaningrum, D. L. (2016). Car drivers with higher perceived safety tend to drive their vehicles with higher risk, a unique phenomenon on the roads in Jakarta, Indonesia. The 2016 International conference on an industrial engineering and operation management (EOM), ICOM. Kuala Lumpur, Malaysia.

Imran, W., Khan, Z. H., Guilliver, T. A., Khattak, K. S., Saeed, S., & Aslam, M. S. (2021). Macroscopic traffic flow characterization for stimuli based on driver reaction. Civil Engineering Journal, 7(1), 1–13. https://doi.org/10.28991/cej-2021-03091632

Iqbal, A., Rehman, Z. U., Ali, S., Ullah, K., & Ghani, U. (2020). Road traffic accident analysis and identification of black spot locations on highway. Civil Engineering Journal, 6(12), 2448–2456. https://doi.org/10.28991/cej-2020-03091629

Ishartono, F., Suhardi, B., & Rohani, J. M. (2020). Ergonomic principles in traffic sign comprehension: A literature review. AIP conference proceedings, 2217, 030055 1–10. Semarang, Indonesia https://doi.org/10.1063/5.0000701

Lady, L., Mulyo, T. T., & Kuminio, K. (2020). Identify factors that caused false and violation by motorcycle rider. IOP conference series: Material science and engineering, 999(1), 012067 1–9. IOP Publishing. https://doi.org/10.1088/1757-899X/999/1/012067

Meis, J., Kashima, Y., & Manalo, E. (2017). Signage as a tool for behavioral change: Direct and indirect routes to understanding the meaning of a sign. PLoS ONE, 12(8), e0182975. https://doi.org/10.1371/jour nal.pone.0182975

Ministry of Research, Technology and Higher Education of the Republic of Indonesia. (2018). Higher educational statistical year book 2018. Republic of Indonesia. https://ppdldik. kemendikbud.go.id/asset/data/publikasi/StatistikPendidikanTinggiIndonesia2018.pdf

Ministry of Transportation of the Republic of Indonesia. (2014). Minister regulation No. PM 13 Year 2014 of traffic signs. In Indonesian. Republic of Indonesia. http://hubdot.dephub.go.id/km/tahun-2014/1626-peraturan-menteri-perhubungan-nomor-pm-13-tahun-2014-tentang-rambu-lalu-lintas

The Indonesian National Police.(2013). Polantas dalam angka tahun 2013. In Indonesian. The Indonesian National Police Headquarters. Korlantas Polri.

Purnamosari, P. (2019). Motorcyclists’ awareness and understanding of traffic signs for traffic safety in Yogyakarta. IOP conference series: materials science and engineering, 615, 012125 1–8. Stuttgart, Germany. https://doi.org/10.1088/1757-899X/615/1/012125

Purnamosari, P., & Ansusanto, D. (2017). Comparison of the behavior of motorists in traffic safety in Yogyakarta special region by gender. MATEC web of conference, 138(07009), 1–8. Seoul, South Korea. https://doi.org/10.1088/1757-899X/2017/138/07009

Salmon, P. M., Lenne, M. G., Walker, G. H., Stanton, N. A., & Fittness, A. (2014). Exploring schema-driven differences in situation awareness across road users: An on-road study of driver, cyclist and motorcyclist situation awareness. Ergonomics, 57(2), 191–209. https://doi.org/10.1080/00140139.2013.867077

Sandu, C. (2013). The influence of road signs on driver’s performance. International Journal of Traffic and Transport Psychology, 1(1), 35–41.

Sanjaya, K. H., Sya’bano, Y. M. K., Hutchinson, S., & Diels, C. (2019). Preliminary investigation of sleep-related driving fatigue experiment in Indonesia. Journal of Mechatronics, Electrical Power and Vehicular Technology, 9(1), 8–16. https://doi.org/10.14203/j.mve.2018.v9s.8-16

Setyaningish, E., Putranoto, L. S., Soegijanto, S., & Soelami, F. X. N. (2018). Analysis of the visual safety perception and the clarity of traffic signs and road markings in the presence of road lighting in straight and curved road. MATEC web of conference, 181, 04001 1–11. Makassar, Indonesia. https://doi.org/10.1051/mateconf/20181804001

Vilchez, J. L. (2019). A method to measure representativity and univocity of traffic signs and to test their effect on movement. MethodX, 6, 115–123. https://doi.org/10.1016/j.methodx.2018.12.018

Wijayanto, T., Marcilio, S. R., & Luftyanto, G. (2018). Visual attention, driving behavior and driving performance among young drivers in sleep-deprived condition. Proceeding of International conference of occupational health and safety (ICOHOS-2017), KnE Life Sciences, 424–434, Bali, Indonesia. https://doi.org/10.18502/kls.v4i5.2573

Winarso, B. (2016). The decoding of traffic signs by motorcycle riders in Jakarta Indonesia. International Journal on Advanced Science Engineering and Information Technology, (3), 1103–1111. https://doi.org/10.18517/ijasest.6.6.1508
