Exploring the Risk Factors for Rear-End Collisions on Indonesian Toll Roads

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Abstract

Rear-end collisions are the most frequent type of collision on toll roads in some countries. The potential risks of rear-end collisions were drivers, vehicles, roads, and the environment. In Indonesia, rear-end collisions frequently occur on the Jakarta-Bogor-Ciawi (Jagorawi), Cikampek-Purwakarta-Padalarang (Cipularang) and Cikopo-Palimanan (Cipali) toll roads. Few previous studies have focused on risky driving behavior phenomena in Indonesia on rear-end collision risks. This study aims to explore the risks of rear-end collisions on Indonesian toll roads especially risky driving behavior. This study conducted a structured interview with 20 drivers and used voice call WhatsApp application. The results showed that the rank (high-low) of rear-end collision risks based on participants' perception were driver, road, environment, and vehicle. Data show that 70% of participants choose to increase their speed to overtake the truck when it is directly in front of their vehicle. In other circumstances, 55% of participants drive at the same speed in a situation where the bus is the lead vehicle. It also happened in 90% of participants facing a passenger vehicle as the lead vehicle. In addition, the interview result show Cipali and Cipularang toll road sections have a high risk for rear-end collisions.

Keywords
Rear-end collisions, Risk factors, Risky Driving Behavior, Toll Roads, Interview

1. Introduction
Rear-end collisions on toll roads can be caused by the interaction of several causal elements including drivers, vehicles, roads, and the environment. However, different driving conditions for each driver can lead to the driving risk that initiates a precipitating event before rear-end collision (Didin and Iridiastadi 2020, Wang et al. 2020, Wu and Wang 2021). The driver's perception time when responding to a precipitating event will affect the high or low status of a rear-end collision(Wu and Wang, 2021). A previous study in the USA found that the severity of rear-end collision accounted for 30% of injuries and 29,7% of property damage (Chen et al., 2019). Several ASEAN countries such as Malaysia, Thailand, and Vietnam have high accident death rate (Nadhirah et al., 2022). According to Statistics Indonesia, collisions on toll roads also caused injury, social and economic losses until Rp.213.866.888,00 in 2018(Badan Pusat Statistik, 2020). Rear-end collisions were the most common types of crashes on Toll Road associated with injury rate, fatality, property damage, social and economic losses (Chen et al. 2019, Shao et al. 2020, Widia et al. 2021).

Previous studies have found that rear-end collisions most often happen with two factors or more at the same time (Wu and Wang 2021). Several risk factors of rear-end collision categorize as the driver, vehicle, environment, and road condition. The driver risk factor is related to driver behavior, driver attention, and driver distraction. The driver distractions were mobile phone and passenger (Chen et al. 2020, Wu and Wang 2021). The driver behavior related to driving risk is based on driver's characteristics (e.g., drivers' psychophysiological state, cognition, driving skill, and traffic rule consciousness (Wang et al. 2020). Previous research also found that Chinese drivers fear rear-end collisions rather than Western drivers based on glance behavior. The different behavior might be justified because the traffic situation in China is more hectic than in Western countries (Pipkorn and Piccinini 2020).

In a previous study, vehicle risk factors related to the type of vehicle, transmissions, speed, and year of vehicle production (Chen et al. 2020, Didin and Iridiastadi 2020, Shao et al. 2020). Occupants in trucks have a lower injury rather than a passenger in cars while rear-end collisions (Shao et al. 2020). Vehicle speed exceeded posted speed limits

with the foggy condition were factors which contribute to severe rear-end collision (Zhang and Hassan 2019). Old manufacturer's vehicles (before 1996) had more chances of injury during rear-end collisions because of the lack of maintenance and safety design(Chen et al. 2019). Although the new safety design automatic emergency braking (AEB) in high technology vehicles was impressive, it has not fully reduced the risk and number of accidents (Cicchino and Zuby 2019).

Previous studies revealed environmental risk factors related to weather, traffic conditions (e.g., weekdays, weekends), and visibility rate (Wang et al. 2020, Wu and Wang 2021). Poor driving vision at night gives passenger car drivers less time to react according to road condition (Shao et al. 2020). The weather and visibility rate are only significant for non-truck on rear-end collisions (Khattak and Targa 2004). In addition, driving in the rainy season is quite dangerous rather than sunny weather (Luo et al. 2020).

The impact of road risk factor in rear-end collision on toll road related to the road surface, tire, construction zone, road geometry, and interchange area (Luo et al. 2020, Wang et al. 2020). Various road conditions, including road type and road characteristics, bring driving comfortableness for the driver (Wang et al. 2020). Road alignment (e.g., road curve and slope) condition on toll roads might affect driving behavior in a critical situation. A previous study has found that the road with a downward slope was safer (Shangguan et al. 2020).

Moreover, based on what has been explained previously, studies related to the risk of rear-end collisions on Indonesian toll roads can be caused by several conditions that may differ from other countries. This is due to the fact that driving conditions on toll roads in each country are different. Toll roads in Indonesia consist of various toll segments in several islands with various driving behavior, especially risky driving behavior. Nevertheless, rear-end collisions have occurred recently on Jakarta-Bogor-Ciawi (Jagorawi), Cikampek-Purwakarta-Padalarang (Cipularang), and Cikopo-Palimanan (Cipali) toll roads and caused various losses. Although some previous studies have identified several factors of rear-end collision risks on the toll road, very few focus their discussion on the rear-end collision condition on Indonesian toll roads to decrease the fatality rate. Our study aims to explore the rear-end collision risk on Indonesia toll road, especially investigating risky driving behavior by obtaining information based on self-report behavior and understanding the driver experience.

2. Methods

This study was conducted through structured interviews to explore the potential rear-end collision risks based on risky driving behavior and driver experience (Kockelman et al., 2004, Lin et al., 2018, Wang et al., 2020). Twenty drivers were recruited for this study (Creswell and Creswell, 2018). All drivers were recruited using purposive sampling. The criteria of the participant were male or female, age (20-64), has driving license type A, experience driving for three years, and experience driving on Jakarta-Bogor-Ciawi (Jagorawi), Cikampek-Purwakarta-Padalarang (Cipularang), and Cikopo-Palimanan (Cipali) toll road. The participants were hired from social media. Participants with completed the criteria interview used a voice call on the WhatsApp application with one interviewer, and the conversation was recorded with participant’s consent. All participant was informed about the purpose of the interview and confidentiality (Lin et al. 2018).

This study used a phone survey instrument developed according to the Driver Attitude Questionnaire (DAQ) and phone survey instrument (Kockelman et al., 2004, Lin et al., 2018, Wang et al., 2020). These studies were conducted with four sections. The first section was questions about driving patterns and awareness of toll roads. The second section explored the rear-ends collisions risk factor based on driver experience. The third section was questions about driving rules on the toll road condition, and the last section was participant demographics. The interviews were recorded and were carefully transcribed verbatim by two reviewers. The interviews were recorded for at least 30 minutes for each participant. The participants were given compensation of 30.000 IDR for attending the interview. This study used excel for categorizing and reporting the data based on frequencies of some subsections which were presented in tabulation diagram, and were calculated (correlation and odds ratio) using SPSS software for each rear-end collisions risk factors, and compared the findings to the literature and stated the limitations and future research (Creswell and Creswell 2018).

3. Results and Discussion

Twenty drivers were recruited for this study. Participants' average age was 28 years old, and 10% were female while 70% were male. All the participants had driving experience on the Jagorawi, Cipularang, and Cipali toll roads. Section

one in this study show average frequently participant who traveled on toll road/ week was 2,55, and the most toll road section that frequently used by the participant was Purbaleunyi (18%), Cikampek (18%), Cipularang (18%), and Cipali (18%). The ownership status of the vehicle was owned by participants (75%), office vehicle (20%), and family vehicle (5%). Most of the types of vehicles used by participants were Minibus (70%), automatic transmission (60%), and year of production in 2015-2021 (60%). Participants usually used toll roads for works (50%) and holidays (40%) with an average speed of 80-100 km/h (85%). In Indonesia Toll roads, there are three types of road sections with a high number of rear-end collisions such as Jagorawi, Cipularang, and Cipali. The highest risk factor based on participants' perception was the Cipali toll road section (70%), and the second was the Cipularang toll road section (30%). The Cipali toll road section has a high rear-ended collision risk because of the flat geometric road with a rough surface, long straight road, made by concrete material causing bumpy road surface, bus driver with reckless driving behaviors and animal carcasses. Moreover, the Cipularang toll road section has declining geometric road conditions (See Table 1). Driver distraction and misjudgment while driving when encountering a critical condition and drowsiness also potentially increase the risk of collision (Purnomo et al. 2021, Wu and Wang 2021). The highest rear-end collision risk of a type leading vehicle was truck (75%) because the truck has a low-speed range (40-60 km/h), the rear signaling condition (warning light), and reckless braking (Schaudt et al., 2013).

However, in the case of the truck being the leading vehicle, the average participant's vehicle was 64,29 km/h with an average safe distance of 51.35 m, and 70% of participants chose to increase the speed and overtake the truck. In other cases, the bus was the leading vehicle. The average number of participants' vehicles was 88.35 km/h with an average safe distance of 47.85 m, and 55% of participants decided drive at the same speed. The bus speed is almost similar to a passenger vehicle, and bus drivers have better control than truck drivers because bus drivers generally carry quite a lot of passengers so they think more about passenger safety. Unfortunately, there are still some bus drivers with reckless driving behavior, especially on the Cipali Toll roads section.

Based on the interview result for the case of a passenger vehicle was the leading vehicle, the average speed of the vehicle was 101.67 km/h with an average safe distance of 47.25 m, and 55% of participants chose to drive at the same speed. The result also shows the average speed of participant driving at night condition was 91.25 km/h with 56.9 m average safe distance. Another case was a participant driving on a rainy day with has average speed of 69.17 km/h and 89.1 m average safe distance. The decreasing average speed and increasing average safe distance because the driver is distracted when driving at night with rainy weather compared to driving in sunny conditions and the weather is quite good (Sheykhfard and Haghighi, 2020).

The results of the correlation test showed three risk factors were of moderate correlation with Rear-end collision in Indonesia toll roads. The relationship between types of vehicles used by the drivers with rear-end collision was of moderate correlation where Cramer's v was 0.314 with odds ratio 0.22 and the high risks leading vehicle also had a moderate correlation. This finding gave an indication that the types of vehicles chosen by the drivers had an involvement as rear-end collision risk (Yan et al. 2005) and based on rear-end collision statistic data in one Indonesian toll road section in January-February 2019 showed 36% of 29 rear-end collisions involved minibuses (striking driver). The vehicle types were also identified as significant risk factors related to traffic environment and injury severity especially in different vehicle roles (striking or struck) on rear-end collisions (Padlo et al. 2005, Shao et al. 2020). In addition, the relationship between the high risk toll road sections has moderate correlation with rear-end collisions in Indonesian toll roads where Cramer's v was 0.314 with odds ratio 0.22. High risk toll road sections are the toll roads that have several safety issues (surface road, road infrastructure, give high rates crash data) (Sarkar et al. 2016). The high risk toll road sections such as Cipularang and Cipali toll road sections have different characteristics even identified as high risk toll road sections in Indonesia toll roads.

Other risk factors to consider in rear-end collisions in Indonesia toll roads are the average speed while driving on rainy day, safe distance behind truck, safe distance behind vehicle and safe distance while driving at night. The statistical test using binary logistic regression with Nagelkerke estimates for R^2 showed 0.103 for average speed while driving on rainy day, 0.146 for safe distance behind a truck, 0.116 for safe distance behind a vehicle, 0.151 for safe distance while driving at night. A possible explanation for these findings is speed of the vehicle during some specific toll road environments have significant impacts on collisions. Drivers gave extra effort for controlling the speed and distance while rainy day (Wu and Wang, 2021). This finding is consistent with rear-end collision risk probability which has highest crash level at night (Jo et al. 2019).

Table 1. Recapitulation Section 1 (Driving Patterns and Awareness of Toll Roads Condition)

Item	Driver (N)	%
Average frequently travels on toll road/week	2.55 (M)	1.6 (S.D.)
Frequently travel on a toll road section in last one month		
- Jakarta-Merak	3	14
- Purwakarta-Cileunyi (Purbaleunyi)	4	18
- Cikampek	4	18
- Cikampek-Purwakarta-Padalarang (Cipularang)	4	18
- Jakarta-Bogor-Ciawi (Jagorawi)	3	14
- Cikopo-Palimanan (Cipali)	4	18
Vehicle ownership status		
- Owner	15	75
- Office	4	20
- Family	1	5
Types of vehicles		
- Sedan	2	10
- City Car	4	20
- Minibus	14	70
Vehicle transmission		
- Automatic	12	60
- Manual	8	40
Year of Vehicle Production		
- < 2010	4	20
- 2010-2015	4	20
- 2015-2021	12	60
The purpose of travel on the toll road		
- Work	10	50
- Holiday	8	40
- Special Occasion	1	5
- Hangout	1	5
Average speed on the toll road (km/h)		
- 80-100	17	85
- >100	3	15
The high-risk toll road section (Cipularang, Cipali, and Jagorawi)		
- Cipali	14	70
- Cipulang	6	30
The high risks leading vehicle (Truck, Bus, car)		
- Truck	13	65
- Car	4	20
- Bus	3	15
Case: Truck was the leading vehicle		
- Participant action: pull away Speed up	14	70

- Participant action: Drive at the same speed	1	5
- Participant action: Slow down, pull away	2	10
- Participant action: change lanes	1	5
- Participant action: ask change lanes	2	10
- Average Speed behind truck (km/h)	64.29 (M)	9.37 (S.D.)
- Average Safe distance (m)	51.35 (M)	40.82 (S.D.)
Case: Bus was the leading vehicle		
- Participant action: pull away Speed up	7	35
- Participant action: Drive at the same speed	11	55
- Participant action: Slow down, pull away	1	5
- Participant action: change lanes	1	5
- Participant action: ask change lanes	0	0
- Average Speed behind Bus (km/h)	88.33 (M)	19.46 (S.D.)
- Average Safe distance (m)	47.85 (M)	41.23 (S.D.)
Case: Passenger Vehicle was the leading vehicle		
- Participant action: pull away Speed up	1	5
- Participant action: Drive at the same speed	18	90
- Participant action: Slow down, pull away	0	0
- Participant action: change lanes	0	0
- Participant action: ask change lanes	1	5
- Average Speed behind Passenger Vehicle (km/h)	101.67 (M)	13.39 (S.D.)
- Average Safe distance (m)	47.25 (M)	39.28 (S.D)
Case: Driving at night		
- Average Speed (km/h)	91.25 (M)	18.07 (S.D.)
- Average Safe distance (m)	56.9 (M)	45.42 (S.D.)
Case: Driving on a rainy day		
- Average Speed (km/h)	69.17 (M)	9.96 (S.D.)
- Average Safe distance (m)	69.1 (M)	57.96 (S.D.)

The second section result shows 40% of participants have not experienced the rear-end collision themselves but they saw the location of rear-end collision condition on the toll road. The effect of rear-end collision on other toll road users was a traffic jam because of the evacuation process. However, the most type of rear-end collision that happened was passenger vehicle hit by passenger vehicle (20%) (See Figure 1). Participants' perceptions show several rear-end collision risk factors were drowsy driving, safe distance, vehicle malfunction, high speed, and reckless braking. The driver attitude (give sign before changing lane, drive based on speed limits, minimum safe distance, use the right lane) has an important role in controlling rear-end collision risk (Higgins et al., 2013, Wu and Wang, 2021) (See Figure 2). The previous study found rear-end collision risk factors were driver, vehicle, environment, and road (Chen et al., 2019). However, the rank of rear-end collision risk based on participant's perception of this study starts with high-risk driver, road, environment, and vehicle.

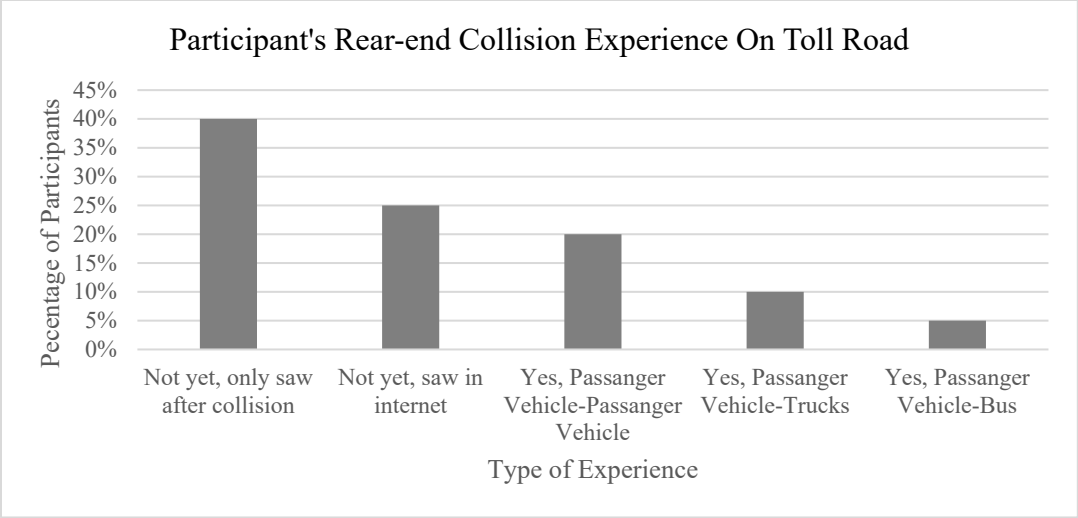

Figure 1. Participant's Rear-End Collision Experience on Toll Road

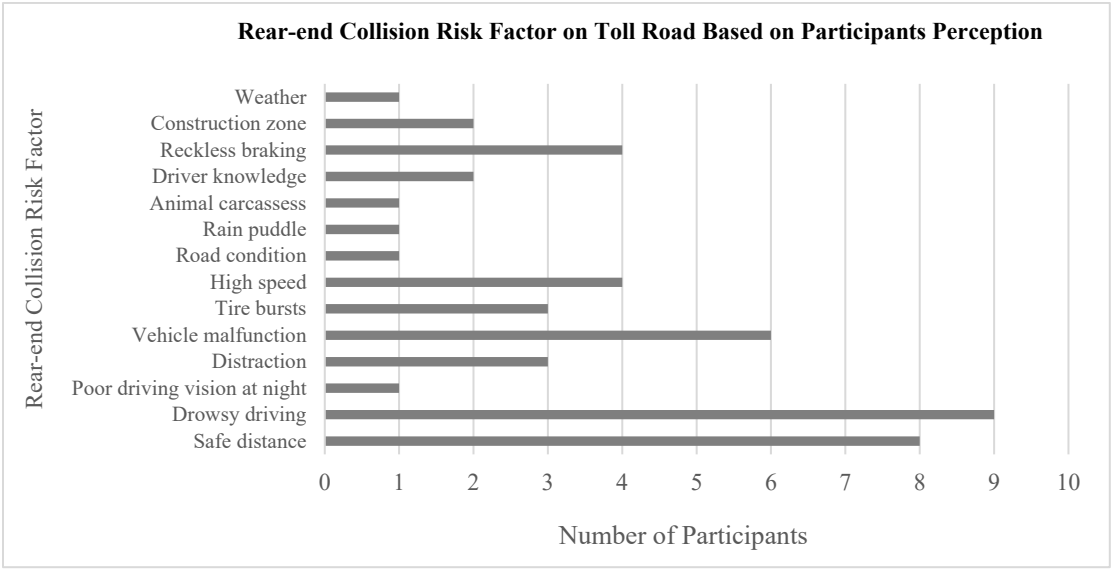

Figure 2. Rear-end Collision Risk Factors on Toll Road Based on Participants Perception

The third section in this study was to explore the participants' knowledge about driving rules on the toll roads. Based on the interview result, the driving rules were speed limits (43%), type of lane (27%), safe distance (14%), check the vehicle condition, driving attitude (2%), seat belts (2%) and driving license (2%). The participant mostly knows about the speed limit, type of lane, and safe distance as potential rear-end collision risk factors. In addition to the functional rules, the existing driving rules need to be supported by the behavior of drivers who obey the rules in several conditions and the cooperation of other drivers who have good driving ethics. Sequential events and combined effects from one or more risk factors might be triggered by rear-end collision event (Wu and Wang, 2021) (See Figure 3).

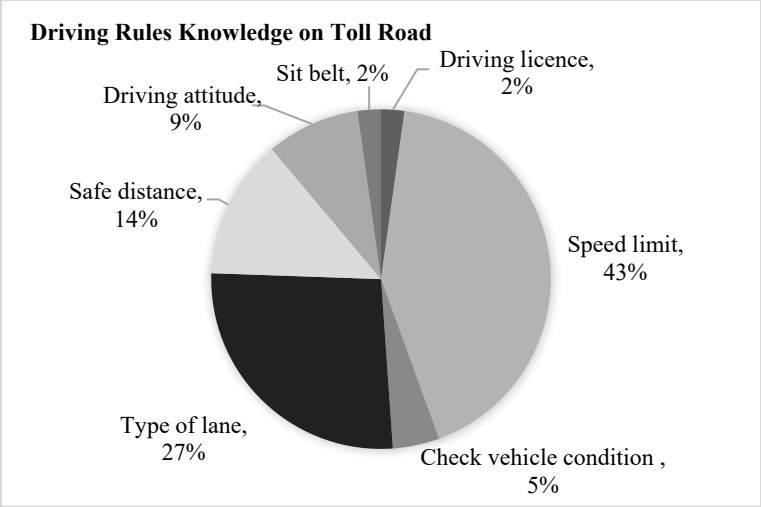

Figure 3. Driving Rules Knowledge on Toll Road

The last section was the demographic of participants with the result showing 60% has driving experience 5-10 years, 45% were private employees, and 45% have last education level in bachelor degree. All of the participants had driving license type A. According to Table 2, there was 60% of participants got a driving license without a test. However, the driving experience is based on how long the participants have a driving license. It might be interesting for future research to learn about the effect of type of driving license on driving behavior.

Table 2. Demographic Information for the Driver Participants

Item	Driver (N)	%
Gender		
- Male	14	70
- Female	6	10
Age	28 (M)	5.9 (S.D.)
Education Level		
- Bachelor	9	45
- Master	6	30
- Junior High School	4	20
- High School	1	5
Occupation		
- Private employee	9	45
- Student	4	20
- Travel Driver	4	20
- Teacher	1	5
- Freelance	1	5
- Secretary	1	5
Driving Experience (year)		
- <5	2	10
- 5-10	12	60
- 10-20	4	20
- >20	2	10
Type of Driving license test		

- Without test	12	60
- Writing test	6	30
- Simulator test	2	10

4. Conclusion

In this study, we explored rear-end collision risks in Indonesian toll roads as a preliminary study based on twenty participants. Several backgrounds of participants including age, occupation, driving experience, etc., were used in this study. The rank (high-low) of rear-end collisions risk based on participants' perception were driver, road, environment, and vehicle. Our interview data show that 70% of participants chose to increase the speed and overtake the truck when facing a truck as the leading vehicle. In another condition, 55% of participants chose to drive at the same speed in the case that the bus was the leading vehicle. It also happened in 90% of participants facing the passenger vehicle as to the leading vehicle. In addition, the interview result shows Cipali dan Cipularang toll road section has a high risk for rear-end collision. This study has several limitations, namely the low sample size which may not represent Indonesian drivers as a whole and the interview process conducted may contain bias. However, more data may be needed for future research, especially surveys with large scale of driving behavior for mitigating rear-end collision risk factors and for developing these research findings.

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