Risk factors for rear-end collision: a systematic literature review

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Abstract. Crash accidents on Indonesia toll road in 2019-2020 as much as 61% of accidents were a type of rear-end collision. That occurs at least two vehicles that act as crashing cars and cars in the hit, resulting in economic and social losses. There is not much research in Indonesia that discusses related to the disaster behind the run. The purpose of this review is to investigate human aspects while driving and gain potential development possible to reduce the rear-end collision. Search engine in this study is Science Direct, PubMed, Taylor & Francis Online, and IEEE. Once obtained, 826 articles carried out the process of checking, and the appropriate characteristics in this study, the result was 13 articles, further conducted a thorough review. Rear-end collision happened because of the contributions of one or all of the risk factor groups factors that have strong evidence (p < 0.001 or OR> 3), including drivers, vehicles, and the environment. This study will increase alertness to the risk factors of rear-end collision on toll roads. Future research intervention can use music, and the traffic density of the driver’s domicile provides an effect on the behavior of drivers who drive with the type of minibus vehicles.

1. Introduction
The development of the infrastructure of toll roads makes increased use of vehicles in Indonesia. The number of accidents in Indonesia has increased gradually since 2017-2018 [1]. While in 2019-2020, 79 accidents occurred on toll roads or freeways with 61% overall the types of accidents are rear-end collision [2,3].

Crash collision on the freeway can occur when the driver interacts with the other vehicle continuously, then the driver accelerations or slows down the driving speed and performs track changes. A collision accident can occur on one vehicle or a single accident, and a continuous accident occurred at a minimum of two vehicles [4] [5]. According to the information from the World Health Organization (WHO), There are 1.35 million people become victims of death caused by traffic accidents. Then the traffic accident caused injuries from low, moderate, and severe levels to death. From 20 to 50 million people suffered an unfatal injury by causing disability of its results [6].

The severity of an injury can be classified, include no injuries, possible injuries, suspected minor injuries, paralyzed injuries, suspected severe injuries, and fatal injuries [6]. Traffic accidents happened caused harm to the victims and roadways from both economic and social factors [7]. Based on the position of the vehicle, several types of collision accidents are the accident of the rear-end collision, front-shelf, side, and other crashes. However, the most common accident event and cause severe injuries and death [6]. Then based on vehicle operation type, there are two various vehicles, automatic vehicles
as well as manual vehicles. The manual vehicle type has limitations on response times and driving errors that impact the rear-end collision [8]. Rear-end collision rises when the vehicle is too close to the other vehicle located in front of it [9] [10]. Based on the type of vehicle, a rear-end collision occurred between a small vehicle (passenger transport vehicle, van, pick up) crashing into other small vehicles, small vehicles crashing into large vehicles (trucks and buses), big vehicles crashing into small vehicles and big vehicles crashing into big vehicles [8,11].

Recently, not much research in Indonesia that discusses related to rear-end collision. Based on the review, this systematic literature review investigates the human aspects of driving relevant to the phenomenon of a rear-end collision in the last two years (2019-2020). Also, it sees potential development that has done to reduce the incidence of the rear-end collision.

2. Methods
2.1 Literature search and data management
The systematic literature review uses four electronic search databases from 2019 to 2020, using the keyword and advance search feature on-site. They are Science Direct, PubMed, Taylor & Francis Online, and IEEE (Institute of Electrical and Electronics Engineers). The keyword is the rear-ended collision, and the process review was using Microsoft Excel and Mendeley software. This systematic literature review search procedure was conducted based on a systematic rule of review of the University of Edinburgh and several other review literature research [12 – 14].

2.2 Included and excluded Criteria
In this systematic literature review, the rear-end collision focused on the vehicle with manual conditions. Here are the criteria of the selected article:
1. Connected to the rear-end collision
2. Year of article publication 2019-2020
3. Report on risk factors that cause rear-end collision
4. Using one of the investigation tools to examine the risk factors of the rear-end collision, such as experiments, simulations, and direct observation.

2.3 Screening process
Initially performed a paper search on the search site using the keyword in advance search feature. After obtaining the paper with the keyword, it checked, and the selection ensures that no paper duplicated. Screening process by checking the abstract of the paper, because the abstract can conduct the formulation of problems and conclusions on the research. Thus, by examining the abstract, a paper is potentially included in the criteria received in the systematic literature review of the rear-end collision.

2.4 Evaluation process
At this stage, evaluating the risk factors of rear-end collisions is seen from the study's significance. Criteria are said to have a strong relationship when having a minimum odds ratio value of 1.0. Besides, the significance value [P-value] also used to classify the risk factor [13]. The risk factors in the rear-hit accident are classified as follows:
1. Risk factors with strong evidence (odds ratio (OR) of > 3 or P-value < 0.001 (P < 0.001)
2. Risk factor with reasonable evidence (OR 1-3 or P-value < 0.05 (P < 0.05)
3. Risk factor with insufficient evidence (OR < 1 and P-value < 1 (P > 0.05)

3. Results
3.1 Literature search and evaluation
The search for the literature review of rear-end collision starting from the year 2019-2020 generates 830 articles from 4 types of search site publishers online research as in the Figure. 1. Each of the search results from databases online such as Science Direct 432 articles, IEEE 11 articles, Taylor & Francis Online 329 articles, and PubMed 58 articles. Then from a total of 830 articles, four articles duplicate
the remaining 826 articles. Further checks related to the title and abstract 798 articles do not match the criteria. Six articles are still incomplete. There are 22 articles reviewed in total and resulted in 9 articles that did not conform to the criteria. For the result, the study of this literature uses 13 articles that examine the risk factors of rear-end collision.

**Figure 1.** Stage of systematic literature review of studies investigating risk factors for rear-end collision

### 3.2 Investigation Tools for Risk Factors of Rear-end Collision

There are several practical investigative tools related to the risk factors of the rear-hit accident covering experiments [15 – 17], Simulation [18] [8], and direct observation [11]. Each method has advantages and disadvantages in its use in research [6].

a. Experiment

Experiments conducted for investigation of risk factors rear-end collision usually use vehicle simulation tools such as OKTAL CDS-650 [15]. A vehicle simulator equipped with the features of manual and automatic vehicle transmission, steering the power steering, there are gas pedals, brakes, TV screens, sound effects using a sound system, human models, and using video recorders [6,16]. Aside from the necessary experimental equipment, research has participant criteria that can participate in the experiment. Then the number of participants following the experiment is adjusted to the number of factors, levels, and conditions of the experiment. The number of participants following the experiment calculated using power statistics so that the data obtained sufficient for research. Participant's criteria in a rear-hit accident experiment seen from gender, age, and driving Experience [16] [15]. Then the experimental conditions carried out the distraction using mobile phones (voice messaging and text messaging) by drivers while driving, differences in the combination of vehicles (cars crashing trucks and car crashing trucks), differences in traffic density situation, and the difference in weather conditions. Before conducting an experiment, participants filled in an approval statement about his participation in the experiment. The statement's content includes explanations of experiments from the
objectives, experimental activity to be conducted, duration of the experiment, compensation of experimentation when there is, and possible risk of experimenting. The participants made in advance the adjustments to the simulators used before taking the actual experimental data. The resulting data of the experiment is processed and analyzed statistically by the researcher. Nevertheless, there are also types of experiments using used vehicles and human models to carry out rear-end hit accidents, but these experiments are not repeatable and expensive [15][16][11][4].

b. Simulation
The simulation used in this study is generally a numerical simulation. This simulation can use to see the impact of injuries from rear-end collisions by using different parameters and combinations. The combination in the simulation can be the difference in speed, vehicle type, weather variation, traffic density, driving duration, and the order of the vehicle in the Journey [4][6][18]. Numerical simulation is one of the most powerful investigative tools. Nevertheless, numerical simulation requires sophisticated modeling, complicated analysis, and some natural conditions in the driver, vehicles, and environments are usually ignored [6].

c. Field Observation
On-the-field observation is done by observing ongoing vehicle journeys or using data recorded from the already occurred rear-end collision. The observation in this field provides complete information and details. Data obtained from field observations include genetic data such as human factors (gender, age, fatigue, sitting position or alcohol use), vehicle factors (vehicle type, vehicle speed, vehicle weight) and environmental factors (road conditions, weather conditions, lighting conditions) [6][19]. Direct observation uses in a particular area that records vehicles at specific points on a journey using sensors and video recorders (1.4). Observation can be done on two observation lines and observe days observation so that results can see what the highest probability of a rear-end collision can occur [4].

3.3 The parameters of rear-end collision
The parameters used to investigate the risk factor of rear-end collision are driving behavior, acceleration, retarding, response time, safety margin, Time Headway (TH), Time-to-Collision (TTC), Variable Speed Limits (VSL), Time Exposed Time-to-Collision (TET), Time Integrated Time-to-Collision (TITE), Total Travel Time (TTT) and Breaking Reaction Time (BRT). The definition of each parameter can explain as follows, driving behavior was observe during the drive in the road used camera [20]. The safety margin is a safety risk level that the driver feels by maintaining a secure distance while driving; this level of risk has an upper and lower limit for the level of risk received [21]. Acceleration and deceleration of vehicle speed observed during the vehicle running according to the research scenario conducted.

Response time is the time needed for the driver to respond to the stimulus of an incident when the driver is driving. TH is the time difference between the upcoming occurrences of two vehicles consecutively at a point of measurement on a track [20]. TTC is the required time for two vehicles to collide if both vehicles continue to use the same speed on the same track [5,20,22,23]. Variable speed limits are the vehicle speed limit set on a driving rule on the road [18]. TET is a summation of all the drivers used when approaching a vehicle in front of it or dangerous traffic conditions during the travel period studied [8,24]. TITE is the summation of entities TTC which is lower than the threshold that expects to express the average duration of a vehicle facing a critical situation or unsafe condition [22,25]. TTT is the primary indicator for assessing the operation and efficiency of the transportation system seen from the time spent by vehicles on the toll road and the number of vehicle-generated systems in the research period [26]. BRT is a vehicle braking reaction time performed by the driver when driving [15].

3.4 Risk Factors of Rear-End Collision
Based on a systematic literature review conducted, there are various risk factors of rear-end collision. In Table. 1 Risk factors are affecting the risk of rear-end collisions. The risk factor rear-end collision grouped into four groups: driver characteristics, vehicle characteristics, collision mechanisms, and
environment. The strong evidence of risk factors over the driver includes driver emotions, male drivers, drivers under the age of 25, drivers over 64 years old, and driver response time. Risk factors that have sensible evidence are a distraction to the driver, driver behavior, driver's ability, gender, and the driver's age. Meanwhile, the risk factor with insufficient evidence is the driver of the female, who is over 64 years old.

In a risk factor group of vehicle characteristics that have strong evidence is a type of truck vehicle, the vehicle carries one or more connections, the vehicle does not have an airbag, year of vehicle production, and seat belts not used while driving. A risk factor with reasonable evidence is that the vehicle is not a passenger vehicle type, and its speed is more than 70 km/h. Then a risk factor collision mechanism that has strong evidence is a driver of text messaging while driving, a driver in the influence of drugs while driving, and a driver in the influence of alcohol while driving. A risk factor that has reasonable evidence is that the vehicle is hit by slowing or stopping, the vehicle continues ahead before the collision, the new vehicle starts to run or stops on the road before the collision, vehicles that hit the direction of the turn, the vehicle that hit the turn, the vehicles crashing to turn and the vehicle crashing changed lanes. The location of vehicle damage is in the direction of 7 hours, the location of the collision's impact on the vehicle body that hit in the direction of 7 hours, and the collision on the track with different the risk factors that have insufficient evidence is oscillation included. Then a group of environmental risk factors that have strong evidence is the road's characteristics and drive during the day at 07.00-18.00. Risk factors that have reasonable evidence are the weather, snowy or icy road surface, driving on weekdays, driving at night, daily traffic density, platoon ratio, and > 12 lux lighting level. A risk factor that has insufficient evidence is driving in spring and traffic conditions that are not too dense.

Table 1. Risk factors rear-end collision

| Risk Factors Group               | Risk Factor                               | Strong evidence | Reasonable evidence | Insufficient evidence | References |
|----------------------------------|-------------------------------------------|-----------------|---------------------|-----------------------|------------|
| Driver Characteristic            | Driver emotion                            | ✓               | ✓                   | ✓                     | [9]        |
|                                  | Distraction                               |                 |                     |                       |            |
|                                  | Male Driver                               | ✓               |                     |                       | [11],[6]   |
|                                  | Female Driver                             |                 |                     | ✓                     | [16]       |
|                                  | Age under 25                              | ✓               | ✓                   |                       | [11],[6]   |
|                                  | Age 64                                    | ✓               | ✓                   |                       | [11],[15],[6] |
|                                  | Driver Behavior                           |                 |                     |                       | [20]       |
|                                  | Driver response Time                      | ✓               |                     |                       |            |
|                                  | Driving Skill                             |                 |                     |                       | [27]       |
|                                  | Gender                                    |                 |                     |                       | [27]       |
|                                  | Age                                       |                 |                     |                       | [27]       |
| Vehicle Characteristic           | Not a passenger vehicle                   |                 | ✓                   |                       | [28]       |
|                                  | Speed more than 70 km/h                   |                 | ✓                   |                       | [28],[27] |
|                                  | Truck                                     | ✓               |                     |                       | [11],[27] |
|                                  | Vehicle carrying one or more trail connections | ✓       |                     |                       |            |
|                                  | No airbag                                  | ✓               |                     |                       | [6]        |
|                                  | Not using seatbelt                        | ✓               |                     |                       | [6]        |
### Table 1. Risk factors rear-end collision

| Risk Factors Group       | Risk Factor                                           | Strong evidence | Reasonable evidence | Insufficient evidence | References |
|--------------------------|-------------------------------------------------------|-----------------|---------------------|------------------------|------------|
| Collision Mechanism      | Vehicle action being hit slows or stops               | √               |                     |                        | [28]       |
|                          | Vehicle continue to advance before collision         | √               |                     |                        | [11]       |
|                          | Vehicle start or stopping on the road before collision| √               |                     |                        | [11]       |
|                          | Vehicle action that was hit by turning                | √               |                     |                        | [28]       |
|                          | Vehicle crashing towards turn                         | √               |                     |                        | [28]       |
|                          | Vehicle changing track                               | √               |                     |                        | [28]       |
|                          | Damage impact in vehicle was hit body                 | √               |                     |                        | [28]       |
|                          | hit in the 1 clock direction                         |                 |                     |                        |            |
|                          | Damage impact in vehicle crashing hit body           | √               |                     |                        | [28]       |
|                          | hit in the 1 clock direction                         |                 |                     |                        |            |
|                          | Collision on same line with different vehicle types  | √               |                     |                        | [4]        |
|                          | Send Voice messaging while driving                   | √               |                     |                        | [16]       |
|                          | Texting while driving                                 |                 |                     |                        | [16]       |
|                          | Driving under alcohol control                        | √               |                     |                        | [6]        |
|                          | Driving under drug control                           | √               |                     |                        | [11],[6]   |
|                          | Oscillation                                           | √               |                     |                        | [18]       |
|                          | Driver Glace                                          |                 |                     | √                      | [7]        |
|                          | Weather                                               | √               |                     |                        | [9],[27]   |
| Environment              | Snowy or icy road surfaces                            | √               |                     |                        | [28],[6]   |
|                          | Weekdays                                              | √               |                     |                        | [11]       |
|                          | Spring                                                | √               |                     |                        | [11]       |
|                          | Night-time                                            | √               |                     |                        | [4]        |
|                          | Uncongested traffic conditions                        | √               |                     |                        | [15]       |
|                          | Traffic density                                       | √               |                     |                        | [29],[27] |
|                          | Road Characteristic                                  |                 |                     |                        | [27]       |
|                          | Daytime 7-18                                         | √               |                     |                        | [6]        |
|                          | Platoon ratio                                         | √               |                     |                        | [5]        |
|                          | Illumination level > 12 Lux                           | √               |                     |                        | [5]        |
Figure 2. Mapping of risk factor relations, the rear-end collision mechanism and the impact of accidents contained

The mapping of risk factor relationships with strong evidence, a rear-hit accident mechanism, and the impact of accidents are present in the image. The rear-end collision occurs influenced by three factors, namely drivers, vehicles, and the environment. Whereas when a rear-end collision occurs, the impact of the collision varies depending on the input causing the collision that occurred before. The impact of this collision began not to suffer injuries until fatal injuries even caused death. The three risk factors of a rear-end collision relate to each other because the driver drove a vehicle driving on the road with a particular environment—a critical driver of the driving system's controller.

4. Discussion

The rear-end collision occurs at least two vehicles having the vehicle crashing role, and the vehicle was hit [28]. Risk factors for rear-end collisions include driver characteristics, vehicle characteristics, accident mechanisms, and environmental mechanisms. In the driver's characteristic, there are different research results related to gender and driver's age risk factors. The male driver has strong evidence as a risk factor for a rear-hit accident [6,11], but there is insufficient evidence that the female driver as a risk factor for a rear-hit accident [16]. On the Age risk factor, which has strong evidence is a driver with age less than 25 years, this is because the driver's age under 25 years old has no control of emotions, the driving ability is quite good [6] [11] [9] [27].

In addition to the response time, the driver has strong evidence as a risk factor for rear-end collision; it relates to the driver's response when responding to the stimulus unexpected conditions of other vehicles and the environment while driving [20]. Response times, such as acceleration or retarding vehicles, relate to the driver's condition of driver characteristics. Each driving driver has a different perception of risk. Driver reaction and risk perception are easily affected by psychological conditions and environmental conditions [20]. Psychological conditions, such as stress, anxiety, and fatigue, are the impact of driving demands. Driver's demands are the driver's characteristic when facing a traffic density situation based on its ability [30.31]. Based on characteristics of the driver differ in this can be seen in the characteristics of drivers who come from 3 cities in Indonesia that have a level of traffic density and the type of car commonly faced by drivers in the city where the driver's residence. The driver's behavior on the toll road differs from that of drivers who dare to take the risk of following the road shoulder, moving on toll roads, and still driving safely. One of the psychological conditions is that the driver's emotion becomes one of the risk factors of an accidental rear crash that has strong evidence [9]. The driver's emotions affect driving conditions. The emotions of the driver can change in the form
of positive and negative emotions. The driver's emotions depend on the task the driver belongs to. The driver who has terrible or unstable emotions will drive fewer maximums, such as not being able to control the speed [32]. Besides, the accident data that occurred on the Indonesian toll road in 2019-2020 showed that 24.05% of 79 accidents were caused by drivers who were unable to control their speed [2.3]. This shows that the findings of the review literature and the reality in Indonesia are quite relevant.

The cause of the second-highest accident on the Indonesia toll road in 2019-2020 is exhausted [2.3]. Fatigue that occurs in the driver can cause drowsiness, focus fatigue until half asleep at a particular driving time or long driving duration [33]. This fatigue condition affects the driver's response time to the traffic density environment. In the field condition of Toll road Indonesia, the driver likes to listen to music while driving to improve comfort, relieve stress, and increase focus. Besides music also, the driver usually listens to the radio. Music that the driver heard can raise the working mental business if the type of music does not match the driving preference [34]. Hence, determining the influence of music on the driver on the Indonesian toll road can be further investigated to reduce the risk of a rear-end collision.

On the risk factor of vehicle characteristics, the risk factor that has strong enough evidence is the type of truck vehicle, the vehicle carrying connections, vehicles not complete with the airbag, seatbelts, and vehicle production of a reasonably old year. Airbag and seat belts themselves have a role in minimizing the injuries experienced by the driver when the collision occurs [6] [11] [27]. The type of truck vehicles that usually do not carry the connection, carrying one connection, even more, has limited driving flexibility when compared to small vehicles. Some factors can be attributed to the risk factor of the rear-end collision mechanism when different types of vehicles are on one line [4]. Meanwhile, the accident on the Indonesian toll road 2019-2020 showed that 41.72% of the 79 accidents occurred in the type of minibus vehicle with the scenario of rear-end collision truck-minibus and minibus-Minibus [2.3]. This type of minibus vehicle is also widely used in Indonesia, and this can be future researched on the accident behind the rear on the type of minibus vehicle.

Meanwhile, the rear-end collision mechanism, which is a text-messaging driver, has strong evidence as a risk factor for rear-end collision-related drivers that have insufficient evidence as a risk factor [16]. Nevertheless, the difference in research results is that there is a difference in the distraction of sending messages using mobile phones on Chinese drivers and western origin. The Chinese truck driver's occurrence of a change of sight on the mobile phone is only 4%-12.5%, while the driver in the West Country is 10%-20% [7]. The rear-crash accident has a risk factor with strong evidence associated with road characteristics [27]. A straight road characteristic is the type of road that often happens to the rear sprinter [28]. Then the risk factors of other rear-end collisions are driving during daylight hours [07.00-18.00], and the night is related to the existing lighting on the road and the traffic density, especially on weekdays [4] [5]. Data that occurred on the Indonesian toll road in the year 2019-2020 showed that 23% of the 79 accidents occurred in two times. Such as in the morning at 05.00-10.00, and 10% occurred during the day at 10.00-15.00. Data shows the findings of the review literature, and the fact in Indonesia is quite relevant for further investigation.

The systematic literature review conducted based on the value of the significant value of the P-value and odds ratio. Then this review shows that the risk factors have a link to the research, and there are differences in the results of previous research. Rear-end collisions occur due to contributions from one or all of the risk factors, including drivers, vehicles, and the environment. The collision mechanism occurs due to distraction in drivers ranging from internal distracting [drug and alcohol use] and external distracting such as mobile phone usage.

5. Conclusion

The systematic literature review shows that many factors are affected by the rear-end collision. Risk factors of rear-end collision divided into driver characteristics, vehicle characteristics, collision mechanisms, and environments. Accidents happened due to the contributions of one or all of the risk factor groups. Risk factors that have strong evidence and relevant to the accident condition in Indonesia toll road is the behavior [emotion], the response time of the driver so that the difficulty controlling the speed, type of vehicle in the form of the minibus, and time of driving at 05.00-18.00. While the
intervention that can use in the future research of external intervention in the driver is music, and the traffic density at the driver's residence originated. This study expects to increase alertness to the risk factors of rear-end collisions on the freeway [toll]. The implications of this study know other risk factors as a preventive action strategy on a rear-end collision on the freeway [toll].

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