Analysis of Safety Distance between Two Moving Vehicles

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Abstract: - Nowadays, there are million of vehicles including passenger cars on the road. With these huge numbers vehicle collision is inevitable due to numerous factors. It has been reported that 60% of the vehicle accidents involved with front end collision between two moving vehicles. This paper attempts to study front end collision of two vehicles that travel in the same lane and later proposes active crash prevention (ACP) system to avoid collision by utilizing tracking device. This device is integrated with an anti-lock brake system (ABS) and it will ensure that the two moving vehicles are separated within a safe distance. In order to investigate front end collision with and without tracking device existing analytical formulation is adopted and fully utilized.

Key-words: - Vehicle collision, Vehicle distance, Tracking device, Brake

1 Introduction

In Malaysia, there are approximately 20.2 million of registered vehicles on the road. Of these numbers, Ministry of Transport Malaysia (MOT) [1] stated that motorcycle has higher percentage with 46.8% followed by passenger car (45.1%), good vehicle (4.8%), taxi (0.4%), bus (0.3%), and others (2.4%) as shown in Fig. 1.

With increasing number of new vehicle registered every year vehicle road accident has appeared to be a big concern not only to MOT but also to the community. It can be seen in Fig. 2 that the number of road accidents has also been increased every year.

Fig. 1. Breakdown of the vehicle types [1]

Fig. 2. Road accidents in 10 years from 2001-2010 [1]

In the view of the detailed breakdown of accident cases by vehicle category as depicted in Fig. 3, it showed that the most vehicles contributed to the accidents was motorcar with 65%, motorcycle with 17%, lorry with 7%, van and four wheel drive with 3%, bus with 2%, taxi with 1% and others with 2%. Consequently, number of causalities and deaths had also been increased in the 10 years period.
Types of accident involving vehicle collision can be classified into three categories, namely front end collision, rear end collision and side collision. Kiyoka et al. [2] in their study suggested that front end collision contributed up to 76% of the fatalities and whilst 19% fatalities were due to rear end collision.

There are numerous factors contributing to the vehicle collision and they are due to driver distraction, error in judgement, careless and error in operation [2]. In other studies, driver distraction and careless were the main cause for vehicle collision [3]. In order to reduce number of road accidents due to vehicle collision safety devices had been put forward and employed [4]. These safety devices are categorized under the intelligent transportation system (ITS) where ITS is a device to cater a problem that’s related to human weakness.

Thus, this paper is first aimed to study front end collision of two vehicles that travel in the same lane and later proposes active crash prevention (ACP) system to avoid collision by utilizing tracking device.

### 2 Collision safety device

There are two categories of collision safety device, namely passive and active safety prevention. Seat belt, air bag, lighting and stronger vehicle frames are under passive safety prevention [5] whilst anti-collision safety devices such as anti-lock braking system (ABS), Adaptive cruise control (ACC), ACC stop and go, pre-crash collision, collision mitigation and etc. are categorised under active safety prevention [6]. Anti-lock braking system, for instance, can help to reduce the stopping distance by increase the traction between tire and road surface [7, 8,] and hence reducing possibility of vehicle collision.

#### 2.1 Braking time and stopping distance

In designing active safety prevention system driver reaction time during the emergency brake condition must be taken into account apart from the braking time [3]. Thus, the total stopping distance and total time to stop the vehicle are based on the driver reaction and braking application as illustrated in Fig. 4.

![Fig. 4. Total braking distance and time](image)

**3 Vehicle Braking Distance Model**

#### 3.1 Modeling of Gap Distance between Host and Leading Vehicle

Luo et al. [9] stated that speed of two vehicles can be given as in Equation (1);

\[
\ddot{x}(t + \tau) = k(\dot{x}(t)_{le} - \dot{x}(t)_{he})
\]

where:

- \( k \) = Gain constant for the response process (\( k =1 \))
- \( \ddot{x}(t + \tau) \) = Acceleration of the lead vehicle
- \( \dot{x}(t)_{le} \) = Speed of the leading vehicle
- \( \dot{x}(t)_{he} \) = Speed of Host vehicle

These two vehicle’s speeds will be used in calculating gap distance between the host and leading vehicles. There are three scenarios in calculating the gap distance:
i) speed of the host vehicle is greater than the leading vehicle

\[ \alpha_{ao} = \dot{x}_{hc} t_r + \frac{\dot{x}_{hc}^2}{2} \left( \frac{\dot{x}_{hc}}{\dot{x}_{hc}^{max}} \right) + l \]  

(2)

ii) speed of the host vehicle is equal to leading car

\[ \alpha_{ao} = \dot{x}_{hc} t_r + \frac{\dot{x}_{hc}^2}{2} \left( \frac{1}{\dot{x}_{hc}^{max}} - \frac{1}{\dot{x}_{hc}^{max}} \right) + l \]  

(3)

iii) speed of the host vehicle is less than the leading vehicle

\[ \alpha_{ao} = \dot{x}_b (t_r + t_l) + \frac{2\ddot{x}_b \dot{x}_b - 2\dot{x}_b^2 - \ddot{x}_h c^2}{2\dot{x}_{hc}^{max}} + \frac{\dot{x}_b^2}{2\dot{x}_{hc}^{max}} - \dot{x}_b t_l + l \]  

(4)

where;
\( \alpha_{ao} \) - Longitudinal gap distance between host vehicle and leading vehicle
\( \dot{x}_{hc} \) - Speed of host vehicle
\( \dot{x}_{lc} \) - Speed of lead Vehicle
\( t_r \) - Driver reaction time [0.8 – 1.0s]
\( t_l \) - Change time of deceleration [0.1 ~ 0.2s]
\( \dot{x}_{hc}^{max} \) - Max deceleration of Host Vehicle
\( \dot{x}_{lc}^{max} \) - Max deceleration of Lead Vehicle
\( l \) - Safety distance between vehicle [2 – 5 m]

\[ x(t)_{app} = \alpha_o : if |x(t)_{lc} - x(t)_{hc}| < \alpha_o \]  

(7)

where;
\( x(t)_{lc} \) - Distance lead vehicle
\( x(t)_{hc} \) - Distance host vehicle
\( x(t)_{app} \) - Distance Gap desired
\( \alpha_o \) - Distance Safety Gap (7m)

4 Results and Discussion
Vehicle distance between two vehicles can be seen in Fig. 5. The host vehicle is initially started at 30m while the lead vehicle is started at distance of 60m. It is found that without tracking device the host vehicle will hit the leading vehicle at approximately \( t = 7s \). However, if the host vehicle is equipped with the tracking device front end collision can be avoided as shown in Fig. 6. It shows that the host vehicle has to keep changing its speed in order to avoid collision with the leading vehicle.
Fig. 7 shows results of the host vehicle distance at three different speeds. It is seen that if speed of the host vehicle is greater than the lead vehicle the driver has to frequently press brake pedal in order to keep the vehicle far enough from the leading vehicle. On contrary, the driver has only to maintain the distance without hit the leading vehicle when speed of the host vehicle is equal or less than the leading vehicle.

![SPEED VEHICLE MODEL](image)

Fig. 7. Distance of the host vehicle at different speeds

5 Conclusion
This paper presents analysis of front end collision between two moving vehicles. First, three scenarios in determining gap distance are presented. Then, vehicle with a tracking device is modeled. The results show that the host vehicle without tracking device is very likely hit the leading vehicle if its speed is greater than the leading car. However, the host vehicle will not be at any time hitting the leading vehicle if it is equipped with the tracking device and its speed either equal or less than the leading vehicle.

References