17-03330

INVESTIGATING REAR-END COLLISION POTENTIAL AT SIGNALIZED URBAN NETWORKS BASED ON DISAGGREGATED SPATIAL SENSOR DATA

Katerina Stylianou[1], Loukas Dimitriou Ph.D[1], Mohamed A.Abdel-Aty Ph.D[2]

[1] Lab. Of Transportation Engineering, Dept. of Civil and Environmental Engineering, University of Cyprus

[2]Dept. Of Civil, Environmental and Construction Engineering, University of Florida

INTRODUCTION

Problem Statement

Rear-end collisions are one of the most frequently occurring crashes. An understanding of the contributing factors and their significant association with rear-end collisions is of practical importance.

Method

The objective of this study is to identify **near-crash phenomena by capturing rear-end collision potentials** at a microscopic level. In order to develop a methodology for evaluating rear-end collision potential in urban networks, this study **utilizes disaggregated vehicle information and car following concepts**. A Risk Index (RI) based on stopping distance was derived, which was used to classify rear-end collision potentials into four classes and for a more detailed analysis, alternative Multinomial Logit (MNL) Models were developed to identify the significant contributing variables for the rear-end collision potentials classes.

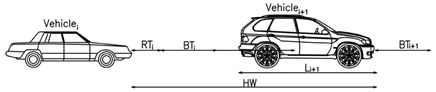
Results

- The proposed classification showed that 70% of car following events examined, were considered as potentially unsafe.
- The higher the flow, the higher are the potentials of engaging in a rear end collision, and at low flows, driver speed has a high variation whereas at higher flows speed presents little variation implying possible coordination.
- Driver characteristics (speed and headway) differ with lane of travel and location in the network
- Leading vehicle size was also found to affect driving characteristics; headways were longer and speeds were lower when large vehicles were involved in the car-following configuration.

METHODOLOGY

The study utilizes disaggregate vehicle information and car-following concepts to evaluate rear-end collision potentials in an urban network. To **estimate a rear-end collision potential a Risk Index (RI) is developed based on stopping distance** calculated using individual speed and temporal headway. The proposed Risk Index (RI) is used to classify the rear end collision potentials as calculated here into four classes.

In an example situation assume that two consecutive vehicles are moving in the same lane. Let Vehicle i+1 be the leading vehicle with a speed V_{i+1} and vehicle i be the following vehicle with a speed Vi, and between the two vehicles exists a time headway, HW. Given this setup the proposed Risk Index (RI), can be derived.



$$
RI = \begin{cases} \text{Class_0, case } HW - L_{i+1} - RT - BT_i > 0 & (1a) \\ \text{Class_1, case } HW - L_{i+1} - RT - BT_i < 0 & (1b) \\ \text{Class_2, case } HW - L_{i+1} + BT_{i+1} - RT - BT_i < 0 & (1c) \\ \text{Class_3, case } S_i - S_{i+1} - S_{HW} < 0 & (1d) \end{cases}
$$

Where:

RI is the risk index for each pair of consecutive vehicles
HW: Headway (s)
L: vehicle length (4.5m for private vehicles & 8.0m for HGV)
RT: Driver's Perception and Reaction Time (=3s)
BT : Brake Time (s) calculated as V/dr
V: Speed (km/hr)
dr: Deceleration Rate of Vehicle (=0.5g m/s^2)
S: Distance Travelled in time t (km) calculated as V*t, t=10s,
S_{HW} : Distance Headway, calculated as V_i*HW

The above RI represents four rear-end collision classes that drivers come under while driving in the urban network, derived by whether they would engage in a potential rear-end collision under different circumstances. As such, **Class_0** indicates the case where a safe distance is kept from the leading vehicle; **Class_1** indicates the case where the distance kept from the leading vehicle is not sufficient in the case of a stationary incident in the road ahead; **Class_2** indicates the case where there is not sufficient distance for the following vehicle to stop when the leading vehicle performs an emergency brake; **Class_3** indicates the case where the distance kept is not sufficient to avoid collision with the leading vehicle in the next 10 seconds if no action is taken.

To accomplish the research objectives loop detector technology was utilized. **Inductive loop detectors (ILD)** allow the collection of individual vehicle information in real-time; based on these disaggregate data the proposed Risk Index (RI) can be derived.

To discover the underlying patterns of contributing factors to rear-end collision potentials an **explanatory analysis** is later employed. In the concept of the urban environment, it was assumed that location (intersections, links, etc.), and even more specifically lane of travel (based on carriageway design) would influence rear-end collision potential classification. Furthermore, **traffic parameters, such as flow, average speed and speed standard deviation, are considered to influence driving style.** Lastly, traffic composition and more specifically **leading vehicle size** is assumed as a contributing factor, since drivers' attention is mainly devoted to the leading vehicle when driving.

Finally, the unordered **Multinomial Logit Model** (MNL) is employed to provide an initial overview of the effects of the traffic and locational variables on rear-end collision potentials.

Speed	Vehicle Spot Speed (km/h)
Headway	Time Headway (s)
Location	ILD Location in Network
Lane	Vehicle's Lane of Travel
Vehicle	Type of Vehicle (Passenger car, HGV)

Disaggregate Data Collected from ILD

RESULTS

Data Collection

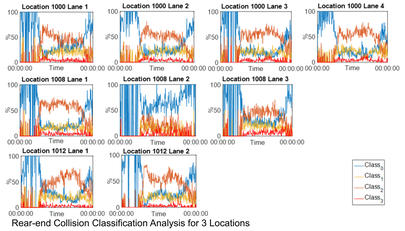
Data was collected from the urban network of Nicosia, Cyprus, including data from 15 inductive loop detectors totaling 46 lanes. The total volume collected for one day was 409,920 vehicles.

Rear-end Collision Classification

Following the proposed classification methodology it was shown that:

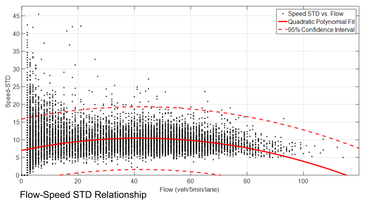
- 30% of the observed car-following events were classified as Class_0
- 19% were classified as Class_1
- 46% were classified as Class_2
- 5% were classified as Class_3

In total, 70% of the observed car following events would be identified as potentially unsafe.

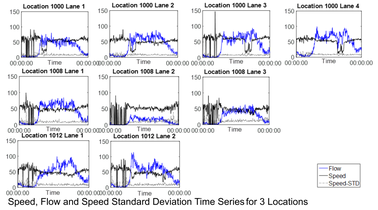


Rear-end Collision Classification Analysis for 3 Locations

Traffic Flow Parameters



Flow-Speed STD Relationship



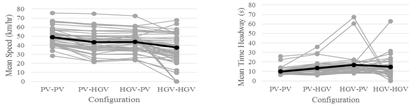
Speed, Flow and Speed Standard Deviation Time Series for 3 Locations

The relationship between flow and speed standard deviation was considered as a good indicator of traffic state. The flow-speed standard deviation curve shows that **speed varies substantially at low traffic flows, but stabilizes at higher flows,** possibly implying traffic coordination.

Comparing the classification analysis to the Flow and Speed timeseries it is shown that **Classes 1,2 and 3 (i.e. cases where rear-end collision is possible) are presented when traffic flow is higher.**

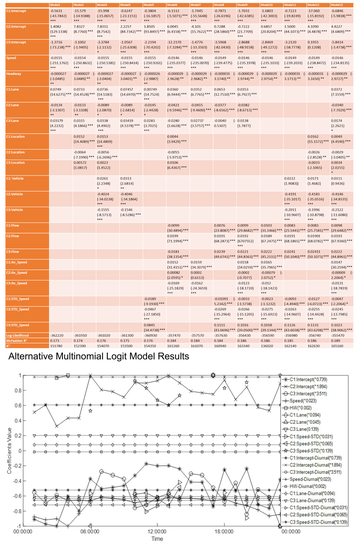
Leading Vehicle Effect

The effects of leading vehicle type on speed and headway of the following vehicle in this study were found to differ according to vehicle size. **It was shown that speeds are lower and headways higher when Heavy Goods Vehicles (HGV) lead.**



Leading Vehicle Effect on Speed and Headway

Multinomial Logit Model Results



Alternative Multinomial Logit Model Results

Diurnal Multinomial Logit Model Results

- **13 Multinomial Logit Models** (MNLs) were evaluated to investigate the significance of the selected variables on rear-end collision potentials.
- The constant specific variables were set as rear-end collision class, the alternative specific variables were speed and headway, whereas individual specific variables consisted of lane of travel, loop detector location, leading vehicle type, flow (aggregated in a 5-minute interval), mean speed (aggregated in a 5-minute interval), and speed standard deviation (aggregated in a 5-minute interval).
- **Not all factors were found to be significant** determinants of rear-end collision potentials.
- The coefficient estimates for the variables of Models 1,4,5,6 and 7 were all found to be statistically **significant at the level of 5%,** and with a McFadden R^2 between 0.17-0.19 indicating an acceptable goodness of fit.
- The signs of the coefficients of the individual specific variables were not consistent, within the different models. This result reflects the fact that different combinations of external factors/ variables influence rear-end collision potentials in different manners, while the model robustness are questionable (multicollinearity).
- For supplementary findings, Model 5 was chosen for an **hourly evaluation**.
- The coefficients of Headway, Lane and Speed-STD were not found to be significant for every hour of the day.
- All the coefficient estimates presented the same sign for each hour implying a **systematic relationship between the examined variables and rear-end collision potential**.

CONCLUSIONS

Rear-end collisions have been identified as a frequent type of traffic crash and have long been studied in the road safety science. The development of effective countermeasures is based on the understanding of the contributing factors to these types of collisions.

- In order for a collision to be avoided, the distance between two consecutive vehicles should be such, as the following vehicle will have the necessary distance to safely stop in the case of a sudden brake or any other emergency situation downstream of the same lane.
- The proposed methodology utilizes easily available data from Inductive Loop Detectors to evaluate rear-end collision potentials.
- It is shown that traffic parameters and vehicle type configuration affect driving behavior and therefore rear-end collision potential.
- Behavioral modeling analysis shows that not all considered variables are found to be significant determinants to rear-end collision potentials and furthermore, variation exists in the significance of the variables in an hourly analysis.