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Investigating Factors Affecting the Occurrence and Severity of Rear-End Crashes

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Abstract

Rear-end crashes are considered as the most frequently occurring types of traffic crashes in many countries. In the Emirate of Abu Dhabi (AD), based on the data of year 2014, the rear-end crashes represented about 20% of total severe crashes and resulted 25% of total crash fatalities. This paper aims to investigate the contributing factors that affect the occurrence and severity of the rear-end crashes in AD. Intensive analyses are conducted regarding; 1) the characteristics of at-fault drivers being involved in rear-end crashes, 2) the main causes of rear-end crashes and 3) the contributing factors affecting the severity of rear-end crashes.

Descriptive statistical analysis and binary logit model approaches are applied to achieve the study objectives. About 17 explanatory variables were tested. The results showed that seven variables are significantly affecting the severity of rear-end crashes. Four variables belong to drivers' characteristic and behaviour including tailgating, driving too fast, years of experience and the issue location of the driving licenses. Two variables related to road characteristics; road type and number of lanes and one variable related to vehicle type.

Keywords: Rear-end crashes, crash severity, crash causes, Abu Dhabi

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1. Introduction

Vehicle to vehicle crashes have been classified based on the collision type into four categories: rear-end, side sweep, head-on and right angle collisions. Rear-end collisions are considered as the most frequently occurring types of crashes over the world and lead to a significant number of injuries and fatalities. For instance, in USA about one third of all crashes were rear end crashes (over 2.5 million rear end collisions are reported every year). These crashes were responsible for 30% of all injuries and fatalities (Sing, 2003). On the other side of the world, Kampen (2000) showed that about 35% of all crashes on Netherlands highways are rear-end against 9% in urban areas. In Japan, about 28% of total series crashes (i.e., crashes involving injuries or fatalities) are rear-end crashes and represent about 35% of crashes at intersections (ITARDA 1998; Wang et al., 2002). However, no information about the rear-end crashes in the middle-east region has been published before. Thus, significant efforts are needed to investigate and identify the contributing factors of rear-end crashes for more understanding of its characteristics and to develop the proper countermeasures in order to reduce its occurrence and severity.

In the Emirate of Abu Dhabi AD, the Capital of UAE, the rear-end collisions represent about 17% of total severe crashes (i.e., any crash with at least one injury). Despite the decreasing trend of the traffic crashes and related fatalities between 2010 and 2014, the contribution of the rear-end crashes in the total crashes increased from 15.8% in year 2010 to 20.4 % in year 2014. In addition, the statistics showed that the severity of the rear-end crashes in AD is significantly higher (179 fatalities/1000 crashes) than the severity of other types of crashes (134 fatalities/1000 crashes). Also, it is worth mentioning that licensed drivers community in Gulf religion is significantly different than other regions in the world. For instance, in AD about 87% of the drivers are foreigners from more than one hundred different nationalities, 85% of the drivers are males and 92% are younger than 45 years old. Despite of these facts, the contributing factors that affect the occurrence and severity of the rear-end crashes have not been explicitly discussed in any prior studies.

This paper mainly aims to provide extensive information and analysis about the contributing factors affect the occurrence and severity of rear-end crashes in Gulf country region based on data collected from Abu Dhabi Emirate. The investigated factors in this study include the characteristics and behavior of at-fault drivers involving in rear-end crashes, crash information, road site characteristics and weather condition. A logistic regression analysis is applied to model and investigate the impact of these factors on the rear-end crash severity.

2. Literature Review

Significant research effort have been undertaken to analyze the characteristics and causes of the rear-end crashes in different parts of the world. Several statistical modeling techniques were utilized to investigate the contribution factors affecting the occurrence and severity of rear-end crashes (Lao, et al. 2014). The majority of the researchers applied linear regression analysis bases in the analysis and modeling process. Abdel-Aty and Abdelwahab (2004) used the nested logit model to estimate the probability of four configurations of car-truck rear-end crashes. The results showed that driver's visibility and inattention in the following vehicle have the largest effect on being involved in a rear-end crashes. The risk or rear-end crashes at signalized intersections was investigated by Yan, et al. (2005) using the multiple regression modeling. The model showed that seven road environment factors (number of lanes, divided/undivided highway, accident time, road surface condition, highway character, urban/rural, and speed limit), five factors related to striking role (vehicle type, driver age, alcohol/drug use, driver residence, and gender), and four factors related to struck role (vehicle type, driver age, driver residence, and gender) are significantly associated with the risk of rear-end accidents. In addition, Wang and Abdal-Aty (2006) applied negative binomial link function for risk analysis at signalized intersections. It was found that traffic volumes, speed, number of legs, right and left-turn proportion are significantly affect the occurrence of the rear-end crashes. Kim et al. (2007) estimated rear-end crash risk at freeways using a modified negative binomial regression. The results showed that urban area, curvature, off-ramp and merge, shoulder width, and merge section are factors found to increase rear-end crash probabilities. Harb et al. (2008) used a conditional logistic regression model to estimate rear-end crash risk in work zone. This model showed that roadway geometry, weather condition, age, gender, lighting condition, residence code, and driving under the influence of alcohol and/or drugs are significant risk factors associated with work-zone crashes. Recently, Bayesian Network BN hybrid approach has been gaining in the analysis of crash severity (Borg et al., 2014; Liang and Lee

2014; Mujalli and de Oña. 2011; Zhao et al., 2012). Chen et al., (2015) developed a multinomial logit model (BN approach) to investigate the contributing factors of rear-end crash severity. The results showed that truck-involvement, inferior lighting conditions, windy weather conditions, the number of vehicles involved, etc. could significantly increase driver injury severities in rear-end crashes. The impact of the driver visibility on the vehicle collision has been investigated by Hassan and Abdal-Aty (2011).

Some researchers used the nonlinear modeling approach to extract more complex interaction relationships between crash severity and the contributing factors (Wong et al., 2007; Abdel-Aty and Haleem, 2011). Lao et al. (2014), applied the generalized nonlinear modeling approach to investigate the relationship between risk of rear-end crashes and independent variable. The results showed for example that truck percentage and grade have a parabolic impact: they increase crash risks initially, but decrease them after the certain thresholds.

Other approaches were applied to quantify the risk of rear-end crashes. Oh et al. (2006) utilized inductive loop detector data to determine the potential of rear-end collision based on fuzzy-clustering algorithm. The results showed that six categories were more appropriate to establish collision risk criteria. Another study in rear-end crashes used loop detectors data was conducted by Pande and Abdal-Aty (2006). It was found that the average speed and occupancy downstream has a significant contribution of rear-end crashes.. In addition, Oh and Kim (2010) utilized the trajectory data of individual vehicles to develop a risk index of the read-end collision. Meng and Qu (2012) used the time to collision TTC data collected from two road tunnel in Singapore to analysis the frequency of Rear-end crashes. Das and Abdel-Aty (2011) applied the Genetic Programing methodology to quantity the risk of rear-end crashes in urban roads. Li et al. (2014) examined the kinematic wave approach to investigate the risk index on rear-end crashes near freeway recurrent bottlenecks. It was found that the likelihood of rear-end collision is highest when the traffic approaching from upstream in near capacity state while downstream traffic is highly congested.

3. Data Description

3.1 Data source

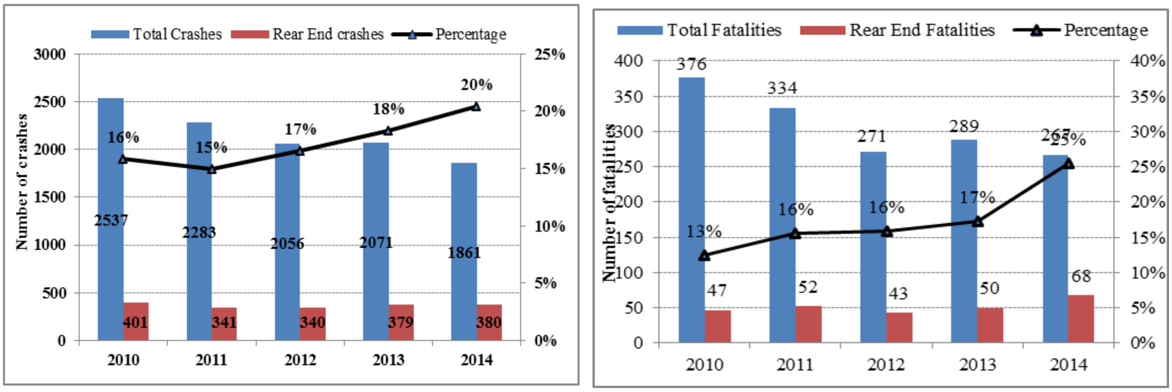
The employed data in this paper was extracted from the database of Abu Dhabi Traffic Police for five years from 2010 to 2014. Severe crash data (i.e. any crash involving at least one injury) are used in this analysis due to the limitation of the available property damage only data. In the database, the severity levels of casualties resulted from traffic crashes are classified into four classes in the database; 1) slight injury, 2) medium injury, 3) severe injury and 4) fatal. Full crash data of about 1,841 rear-end crashes has been extracted and involved in the analysis. It is worth mentioning that the drivers' community in AD is unique because it consists of more than one hundred different nationalities. In addition, male drivers represent 85% of total number of licensed drivers and 92% has age less than 45 years.

To achieve the first two objectives of the this research, detailed descriptive statistical analysis will be conducted. The investigation of the contributing factor that affect the severity of rear-end crashes will be conducted by using multi-level modeling approach.

3.2. Descriptive analysis of rear-end crashes and relevant at-fault drivers

3.2.1. Occurrence of rear-end crashes

A total of 1,841 rear-end crashes, from total severe crashes of 10,808 (about 17%), were recorded in the dataset between year 2010 and 2014. Figures 1-a) and b) show the share ratio of the rear-end crashes and fatalities from year 2010 to 2014, respectively. It shows a significant improvement in road safety in terms of total number of crashes and facilities. However, the contribution ratio of rear-end crashes and related fatalities are in increasing trend.



a) Crash number **b) Fatality number**

Figure 1: Rear-end crashes contribution in total crashes and fatalities

3.2.2. Severity of rear-end crashes

The injury-severity level resulted from the rear-end crashes showed that the rear-end crash fatalities represent about 7% of total road fatalities, 8% of severe injury, 40% of medium injury and 45% of sight injury. Table 1 illustrates the number and percentages of the different injury-severity levels in both cases of rear-end and other crash types observed from 2010 to 2014. In addition, Table 2 shows a severity comparison of rear-end and non-rear-end crashes measured as the number of fatalities rate per 1000 crashes. It shows that the average severity of rear-end are increasing during the last five years. However, the severity of other crashes is in decreasing trend.

Table 1: Injury severity level statistics in AD from year 2010 to 2014

Injury-severity level	Rear-end crashes		Other crashes	
	Number	Percentage	Number	Percentage
Slight injury	1645	45%	5723	39%
Medium injury	1443	40%	6383	43%
Severe injury	287	8%	1473	10%
Fatality	260	7%	1277	9%

Table 2: Crash severity (number of fatalities per 1000 crashes)

Crash type	2010	2011	2012	2013	2014	overall	% of change (in 2014 based on 2010)
Rear-end	117	152	126	132	179	141	53%
Others	154	145	133	141	134	142	-13%

3.2.3. Characteristics of at-fault drivers involved in rear-end crashes

The characteristics of at-fault drivers involved in the rear-end crashes are shown in Table 3 It shows that male, young drivers and Asian nationalities contribute in both crash types more than female, older drivers and other nationalities. This result can be simply interpreted due to the high contribution ratio of male, young drivers and Asian nationality in the licensed drivers' population in AD. It can also be recognized that no significant differences between the contribution ratio of gender, age and nationality for both crash types. However, the contribution of the low educated drivers in rear-end crashes is significantly higher than that in other crash types. Note that the male drivers in AD represent about 85% of total licensed drivers and the drivers' aged between 18 and 25 years old represent about 25% of total drivers.

Table 3: Characteristics of at-fault drivers involved in rear-end crashes

Driver variables		Rear-end crashes		Other crashes	
		Number	Percentage	Number	Percentage
Gender	Male	1773	93%	8127	90%
	female	133	7%	951	10%
Age	(18-25)	535	28%	2466	28%
	(26-35)	694	37%	3300	37%
	(36-45)	370	20%	1719	19%
	> 45	288	15%	1350	15%
Nationality	Locals	629	33%	2881	32%
	Arabian	447	23%	2195	24%
	Asian	787	41%	3757	41%
	Other	44	2%	245	3%
Education level	Low	1745	92%	5040	56%
	High	159	8%	4006	44%
Number years of experience	(0-4)	455	24%	2451	27%
	(5-9)	718	37%	3178	34%
	(10-14)	289	15%	1195	13%
	≥ 15	265	14%	1213	13%
	Unknown	208	11%	1188	13%

3.2.4. Characteristics of rear-end crashes

Table 4 illustrates the characteristics and main causes of rear-end crashes occurred in AD. Regarding the road features, it is found that the majority of the severe rear-end crashes occurred on rural roads (61%) and at non-intersection segments (91%). The data reveals that the rear-end crashes increase with increasing the speed limit of roads. Also, the rear-end crashes increase in the morning and evening time which is synchronized with the peak periods. The majority of roads are high illuminated in AD and weather almost dry all the year, so the results reflected these facts and the majority of rear-end crashes occurred at enough light, dry surface and clear weather conditions. Regarding the main causes of rear-end crashes, it was found that tailgating is the leader (about 54%), followed by sudden lane change and speeding.

4. Model development

4.1 Modelling technique

Binary logit model is considered as a powerful technique to investigate the contributing factors of crash occurrence and severity. A significant number of prior studies applied this model to examine the association between crash, road, driver and vehicle characteristics and crash severity. S. Dissanyake and U. Roy, 2013, investigated the driver, vehicle, road, crash, and environment related factors that influence crash severity are identified by using binary logit model. Another study conducted by Zhu et al., 2010, attempted to predict fatal crash severity for two lane rural highways in the Southeastern United States. Young et al. 2007 estimated the relationship between wind speed and overturning truck crashes. Liu et al., 2009 used this kind of models to examine different factors affecting crash severity on gravel roads. A study aimed to determine the effectiveness of seat belts in reducing injuries by applying logit model was conducted by Ratnayake, 2006. Therefore, binary logit model is used in this paper to investigate the contributing factor of rear-end crash severity in AD.

Table 4: Characteristics of severe rear-end crashes occurring in AD

(Road/vehicle/crash/ environments) Variables		Category	Percentage
Road features	Road Type	Rural	61%
		Urban	39%
	Speed Limit	40 kph	7%
		60 kph	24%
		80 kph	19%
		100 kph	20%
		≥ 120 kph	30%
	Intersection-related	At intersections	6%
		Non-intersection segments	92%
	Number of lanes	≤ 2 lanes	31%
		3 lanes	28%
		≥ 4 lanes	26%
	Surrounding land use	Residential/commercial	31%
		Public services	15%
		Others	54%
Vehicle feature	Vehicle type	Passenger cars	80%
		Heavy vehicle	17%
Environmental	Light condition	Enough light (day time/night with high illumination)	94%
		Other (night with low or without illumination)	6%
	Weather	Clear	96%
		Unclear	4%
	Surface road condition	Dry	97%
		Other (wet/sand)	3%
	Day Time	Morning	28%
		at Noon	26%
		After noon	12%
		Evening	34%
	Day of week	Weekend days	23%
		Working days	77%
Crash Feature	Crash Causes	Sudden lane change	14%
		Speeding	10%
		Alcohol	5%
		Sleepy	1%
		Tailgating	54%
		Reckless	7%
		Dangerous Road Access	4%
		Others	5%

4.2 Explanatory variables

The severity of rear-end crashes (the independent variable in the model) is defined as binary variable (i.e., fatal crashes =1 vs injury crashes =0). The binary definition and characteristics of the examined explanatory variables (i.e., dependent variable in the model) is shown in Table (5). It shows that about 14 explanatory variables are examined in the modelling process.

Table 5: Description of explanatory variable

No.	Variable name	Description
1	GENDER_OF_CAUSES[(a)]	=1 if the driver is a male, =0 otherwise
2	DRIVERS_EXPERIENCE	=1 if the driver caused rear-end crash experience between (0-4)years, =0 otherwise
3	EDUCATION	=1 if the driver finished high school or academic, =0 otherwise
4	LICST	=1 If the driver has the license in Abu Dhabi, =0 otherwise
5	OLDDR	=1 if the driver older than 50 years, =0 otherwise
6	YOUNGDR	=1 if the driver is between 18 and 24 years, =0 otherwise
7	DR_TOO_FAST	=1 If the driver is too fast for conditions or exceeded posted speed limit, =0 otherwise
8	TAILGATING	=1 if the crash occurred due to Tailgating, =0 otherwise
9	ROAD_TYPE	=1 if crash occurred on Rural area, =0 otherwise
10	NO_OF_LANES	=1 if the number of approaches ≥ 4, =0 otherwise
11	INTERSECTION_RELATED	=1 if crash occurred on signalized intersections, =0 otherwise
12	VEHICLE_TYPE	=1 if the vehicle caused crash is light vehicle, =0 otherwise
13	DAYLIGHT	=1 If crashes occur during daylight, =0 otherwise
14	WEEKEND	=1 If the crashes occur during weekend (Friday & Saturday), =0 otherwise

4.3 Model development

In the binary logistic regression analysis, the dependent variable (crash severity in our case) y takes the form of either of the two binary values (0 or 1). For k explanatory variables and i =1, 2, 3, ..n individuals, the model takes the form as follows. Then, the binary logit model can be written in the following form:

$$log\left[\frac{P_i}{1-P_i}\right] = \alpha + \beta_1 x_{i1} + \beta_2 x_{i2} + \cdots + \beta_k x_{ik}$$

P_i = Prob. ($y_i = y_1 / X_i$) is the response probability to be modelled, and y_1 is the first ordered level of y,
α = Intercept parameter,
β = Vector of slope parameters,
X_i= Vector of explanatory variables.

The odds ratio for dichotomous explanatory variable, x, which takes value 1 or 0 (with 1 meaning that the event will certainly occur and 0 meaning that the event will definitely not occur) can be represented as the ratio of the expected number of times that an event will occur (x = 1) to the expected number of times it will not occur (x = 0). This can be illustrated by the flowing formula.

$$\text{OR} = \frac{\pi\,(1)/[1-\pi(1)]}{\pi\,(0)/[1-\pi(0)]}$$

Where,

OR = Odd Ratio

$\pi\,(1)/[1-\pi(1)]$ = Probability that the event will occur when X=1

$\pi\,(0)/[1-\pi(0)]$ = Probability that the event will occur when X=0

5. Results and discussions

Firstly, all the explanatory variables discussed before were used in the modelling process. Then the variables that have an impact of the rear-end crash severity with significant level more than 90% (i.e., $\alpha \geq 0.90$) were involved in the model development process. A total number of crashes of 1,839 crash records were utilized. The Odds Ratio is directly related to the probability of having a more severe crash. The variable with positive Odds ratio denotes the increasing probability of a certain crash severity and vice versa. The final result of the statistical analysis of the fit model is shown in Table 6. Among the tested variables, seven variable are significantly affect the severity of the rear-end crashes in AD at a significant level of 95% in the final model. These variables varied between the road parameters, driver behavior and vehicle characteristics. Among these seven variables, four variables are refer to the drivers' characteristic and behavior; tailgating, driving too fast, total year number of experience and the issue location of the driving licenses. The road variables include road type and number of lanes. Finally, the vehicle type variable which belongs to the vehicle characteristics is significantly affects the rear-end crash severity.

The odds ratios presented measure the amount by which the crash severity increases. Taking an example of the explanatory variable DR_TOO_FAST, which has an odds ratio of 1.923, it can be stated that the probability of fatal crash is about 1.923 times higher in cases of speeding which include driving with speed exceed the speed limit, assuming that rest of the factors remains the same

Table 6: Estimation results and model fit statistics of binary logit model

Variable	B	Standard Error	Wald Chi-square	DF	Sig. (α)	Odds Ratio
ROAD_TYPE	1.060	.204	26.909	1	.000	2.886
NO_OF_LANES	-.589	.199	8.800	1	.003	.555
TAILGATING	-.745	.162	21.071	1	.000	.475
VEHICLE_TYPE	-.366	.175	4.393	1	.036	.694
DRIVERS_EXPERIENCE	-.488	.198	6.114	1	.013	.614
DR_TOO_FAST	.654	.225	8.467	1	.004	1.923
LICST	-.336	.155	4.738	1	.030	.714
Constant	-1.845	.262	49.592	1	.000	.158

Table 6 indicates that the likelihood to be involved in fatal rear-end crashes in rural roads is significantly high compared with urban street. In addition, increasing number of lanes lead to low probability of fatality. That may be explained by that increasing number of lanes give the driver chance to maneuver and avoid hazard situation. Regarding vehicle variables, the results revealed that truck involvement crashes have higher probability of fatal rear-end crashes.

Regarding the drivers' behavior variables, the tailgating increases the probability to involve in injury-crash rather than fatal-crash. However, speeding shows significantly high probability tendency towards the fatal crashes. This results reveal that speeding with tailgating leads to a very critical condition of rear-end crashes. Regarding drivers characteristics, it can be concluded that drivers who issued the driving licenses from AD and have driving experience between (0 - 4 driving years) have lower probability to be involved in fatal rear-end crashes than to be involved in injury crashes. This can be explained due to the familiarity of AD licensed drivers than others and the new drivers (especially foreigners) are more careful during driving.

Considering the results of prior studies, it can be realized that the impact of the driver's factors (i.e., tailgating and speeding), vehicle factors and road factors on crash severity are consistence with the findings of previous researches (i.e., Abdel-Aty and Abdelwahab, (2004); Yan, et al., (2005); Chen et al., (2015)). However, drivers' age and gender showed insignificant impact on the rear-end crash severity in AD. This is in contrast with the findings of prior studies. This can be explained due to the unique composition of the drivers' population in AD as the majority of licensed drivers are young (i.e., over 92% under 45 years old and 0.5% over 60 years old). In addition, male drivers represent 85% of total licensed drivers in AD. This study shows a new variable (i.e., driver experience) as a significant variable affects the rear-end crash severity.

6. Conclusion and recommendations

Both statistical descriptive analysis and modeling approaches were applied in order to investigate the contribution variables affecting the severity rear-end crash by using data collected from AD between year 2010 and 2014. Despite the decline trend in the total number of crashes in AD over the past five years, the participation rate of rear-end crashes increased. Data shows that the majority of the severe rear-end crashes occurred on rural roads (61%) and at non-intersection road segments (91%). In addition, the severity of rear-end crashes increased from 117 fatalities per 1,000 crashes in 2010 up to 179 fatalities per 1,000 crashes in 2014. However, the average severity for both rear-ends and other crashes are approximately the same.

The contributing factors of rear-end crash severity have been investigated by applying binary logit model technique. The model had been developed by using 1,839 crash records. After several trials of molding process, seven variables was found to be significantly affect the severity of rear-end crashes at a significant level of 0.95. Among these variables, four variables are refer to the drivers' characteristic and behavior; tailgating, driving too fast, number year of experience and the issue location of the driving licenses, two variables related to road characteristics; road type and number of lanes and one variable refer to vehicle type.

The results showed that the likelihood to be involved in fatal rear-end crashes increase in rural roads is 2.889 times higher than in urban roads and 1.923 times with speeding behavior of drivers. However, the probability to be involved in injury rear-end crashes increase in cases of tailgating, AD licensed drivers, driving experience between 0 and 4 years and passenger car type. Also, it was found that the severity of rear-end crashes been safer on relatively wider roads (road with 4 lanes or more).

Based on the findings a significant effort is needed to improve the drivers' behavior especially in terms of speeding and tailgating. Traffic rule enforcement and drivers' education and awareness are the powerful tolls to enhance such drivers' behavior, especially in a unique drivers' community like in AD. Further research is desirable to enhance the developed model performance and better understand of the contribution variables affecting rear-end crashes in AD by adding the property damage only crash data to the analysis process which is currently unavailable for the researchers.

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