INFLUENTIAL FACTORS OF RIGHT-TURN VIOLATION DURING CONCURRENT TRAFFIC/PEDESTRIAN SIGNAL TIMING

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ABSTRACT

Studies have shown that in the US, pedestrian crashes often involve vehicle turning at intersections. This study provides insight into the influential factors that are associated with the right-turn violation on green during concurrent vehicle/pedestrian signal timing. This type of violation occurs by failing to yield to the pedestrian crossing the street. Influential factors include driver characteristics, vehicle features, and environmental factors. For this study, field observations were conducted within Los Angeles County. A multinomial-logistic regression model was then applied to determine the influential factors. A detailed analysis was then performed to analyze the impact of these factors on the right-turn violation.

PROJECT DESCRIPTION/OBJECTIVE

California Vehicle Code Section 21950 (a) states that "the driver of a vehicle shall yield the right-of-way to a pedestrian crossing the roadway within any marked crosswalk or within any unmarked crosswalk at an intersection" [3]. The operational framework for concurrent traffic/pedestrian service in the Manual on Uniform Traffic Control Devices (MUTCD) assumes that drivers yield to pedestrians since they legally have the right-of-way [7]. However, studies and observations indicate that this statement is not always valid [5]. If the driver disobeys the right-of-way, the pedestrian's safety and mobility is at risk. Moreover, pedestrians' safety at signalized intersections may be decreasing over time due to increasing the number of aggressive drivers and drivers' failure to yield to the pedestrians at urban areas [4]. One of the areas that need to be addressed happens when a vehicle is about to make a right turn on green signal and a pedestrian is about to cross the crosswalk. This scenario is referred as the right-turn violation on green (RTOG) during concurrent traffic/vehicle signal timing. A study by Sarah M. L. et al. [6] examined the factors that influenced changes in delaying, change of travel pathway or alternations in travel speed of pedestrians. Bourquin et al. [1] evaluated the drivers' yields and delays when making right-turns on green traffic signal, in response to visually-impaired pedestrian behaviors, and observed that taking a reversible step had the greatest impact on drivers' yielding behavior, along with flagging a cane, putting a hand up toward the driver and taking a step into the street. Yu et al. [9] noted that vehicle turning right speed must not be too slow or too fast while making a right turn from major to minor road. A research was conducted by Quistburg et al. [8] on the risk factors of pedestrian-vehicle collisions at intersections found that locations with higher employment density and office uses, roads designed for heavier vehicle volumes, and intersections with signals or marked crosswalks had higher rate of collisions. Building on the current literature, the intent of this study is to identify the significant contributory factors influencing RTOG during concurrent traffic/pedestrian signal timing by applying a multinomial logistic regression model.

DATA COLLECTION

Data for this project were collected by field observations for 20 intersections within Los Angeles County, during the months of January, February and March of 2016. As stated before, the main focus of this study is to discover the most influential factors for right-turn violation on green during concurrent traffic/pedestrian signal timing. In this project, right-turn violation is classified into three (3) types:

I. Violation Type (1): This type of violation occurs when the vehicle is about to make the right turn while the traffic signal is green, and the pedestrian is about to enter the crosswalk. The vehicle violates the right-of-way, and makes the right turn without yielding to the pedestrian. In this project, Violation Type 1 is assumed to be the most dangerous violation since there is the risk that the pedestrian might dart out on the road and the vehicle collides with the pedestrian. The pedestrians place their faith in the right-of-way and assume that the drivers yield to them.

II. Violation Type (2): This type happens when the pedestrian has crossed half of the crosswalk at the most (he/she is on the first half of the crosswalk) and the vehicle makes the right turn.

III. Violation Type (3): This type of violation occurs when the pedestrian has crossed at least half of the crosswalk (he/she is on the second half of the crosswalk) and the vehicle makes the right turn. This type is known to be the least dangerous violation type among the other two types.

The following factors were observed for the purpose of determining their correlation with the Violation Type: Driver's Gender, Vehicle Type, Driver's Age, Crosswalk Type, number of Lanes, presence of Median, Area Type and the Speed Limit. Explanatory variables can be categorical or continuous. Driver's Gender, Vehicle Type, Driver's Age, Crosswalk Type, Median and Area Type are categorical ones, which have two or more categories, and number of Lanes that the pedestrian is crossing and Speed Limit are continuous variables. In this study, number of Lanes that the pedestrian is crossing can take any value between 3 and 10, and Speed Limit can take any value between 25 and 45 (in 5-unit increments). All the variables' name, types, possible values and their baseline are shown in Table 1.

Table 1. Variable Characteristics

Item Name	Variable Name	Variable Type	Independent/ Dependent Variable	Possible Values	Baseline
Violation Type	**VIOLTYPE**	Categorical	Dependent	Violation Type 1 Violation Type 2 Violation Type 3	Violation Type 1
Driver's Gender	**DRIVERGENDER**	Categorical	Independent	0 – Male 1 – Female	0 - Male
Vehicle Type	**VEHTYPE**	Categorical	Independent	Coupe SUV Van Sedan Truck	Coupe
Driver's Age	**DRIVERAGE**	Categorical	Independent	Middle-aged Young Old	Middle-aged
Crosswalk Type	**CROSSTYPE**	Categorical	Independent	Continental Standard Zebra	Continental
Number of Lanes Pedestrian is Crossing	**LANES**	Continuous	Independent	3 to 10	NA
Median	**MEDIAN**	Categorical	Independent	0 – Street without Median	0 – Street

				1 – Street With Median	without Median
Area Type	**AREATYPE**	Categorical	Independent	CBD Residential	CBD
Speed Limit	**SPEEDLIMIT**	Categorical	Independent	25 to 45	NA

METHODOLOGY AND RESULTS

The model used in this project is the Generalized Linear Model (GLM). GLM is a class of statistical model, which explains how a dependent variable can be described by a set of explanatory variables. As stated before, in this study the response variable has more than two levels. Violation Type can be one of the three types, which were explained before. Therefore, Multinomial Logistic Regression Model (MLR) was used, which is a type of GLM. MLR models how the multinomial response variable depends on a set of explanatory variables [2]. It estimates the individual effects of categorical and continuous independent variables on the categorical dependent variable. The model can be expressed by the following equation:

$$Log\left(\frac{\Pr(Y=i)}{\Pr(Y=i')}\right) = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k \quad (1)$$

The intercept β_o is the value of Y when all of the independent variables are equal to zero. β_1, β_2,..,β_k are the regression coefficients of X_1, X_2,…, X_k . This model estimates the effect of each explanatory variable on the probability of committing Violation Type 2 or Type 3 over Type 1. The initial model was named "model1", which explores the correlation of all of the independent variables with Violation Type. After running the multinomial logistic regression model, the statistically significant factors at 90% confidence interval were identified. Based on the result, Driver's Gender, Vehicle Type, Driver's Age, Crosswalk Type, number of Lanes that the pedestrian is crossing and Area Type were determined as the most influential factors. The MLR model, named "model2", was applied for an additional time to confirm the correlation between the determined significant factors only with the Violation Type, as well as discarding the insignificant factors. Median and Speed Limit were omitted in "model2" since these factors were statistically insignificant.

It should be noted that the number of observations were 400, of which 238 were male drivers and 162 were female drivers. As shown in Table 2, the number of males who commit Violation Type 1 is almost five times as the number of females. This implies that in this study, male drivers seem to act more aggressively than female drivers in their right-turn behavior during concurrent vehicle/pedestrian signal timing. A similar trend is observed for Violation Type 2 as well. In case of Violation Type 3, which is the least dangerous, more female drivers are found to be the culprits. Overall, female drivers seem to act more cautiously than male drivers when making a right-turn.

Table 2. Summary Statistics of Violation Types and Driver's Gender

Driver's Gender	Violation Type 1	Violation Type 2	Violation Type 3	Total
Male	36	141	61	238
Female	7	79	76	162
Total	43	220	138	400

Table 3 verifies the validity of running regression model to "model1" and "model2" with regard to Vehicle Type. By running the regression model to "model1" and "model2", it was concluded that "vans" tend to commit Violation Type 1 more than Violation Type 2, in comparison with the baseline, which was "coupe". The ratio of the "vans" committing Violation Type 1 to Violation Type 2 is $\frac{9}{21}$ = 0.4285. The ratio of the "coupes" committing Violation Type 1 to Violation Type 2 is $\frac{3}{25}$ = 0.12.

Table 3. Summary Statistics of Violation Types and Vehicle Types

Vehicle Type	Violation Type 1	Violation Type 2	Violation Type 3	Total
Coupe	3	25	2	30
Sedan	13	87	101	204
Van	9	21	15	45
Truck	8	42	3	53
SUV	10	45	16	71
Total	43	220	137	400

Figure 1 illustrates Violation Types and Crosswalk Types. The ratio of the vehicles that commit Violation Type 2 over Violation Type 1 in the intersections with "standard" crosswalk types is $\frac{125}{18}$ = 6.94. The ratio of the vehicles that commit Violation Type 2 over Violation Type 1 in the intersections with "continental" crosswalk types is $\frac{72}{27}$ = 2.66. In this study, the ratio of the vehicles that commit Violation Type 2 over Violation Type 1 in intersections with "standard" crosswalk type is higher than the same ratio in the intersections with "continental" crosswalk type.

Figure 1. Violation Types and Area Types

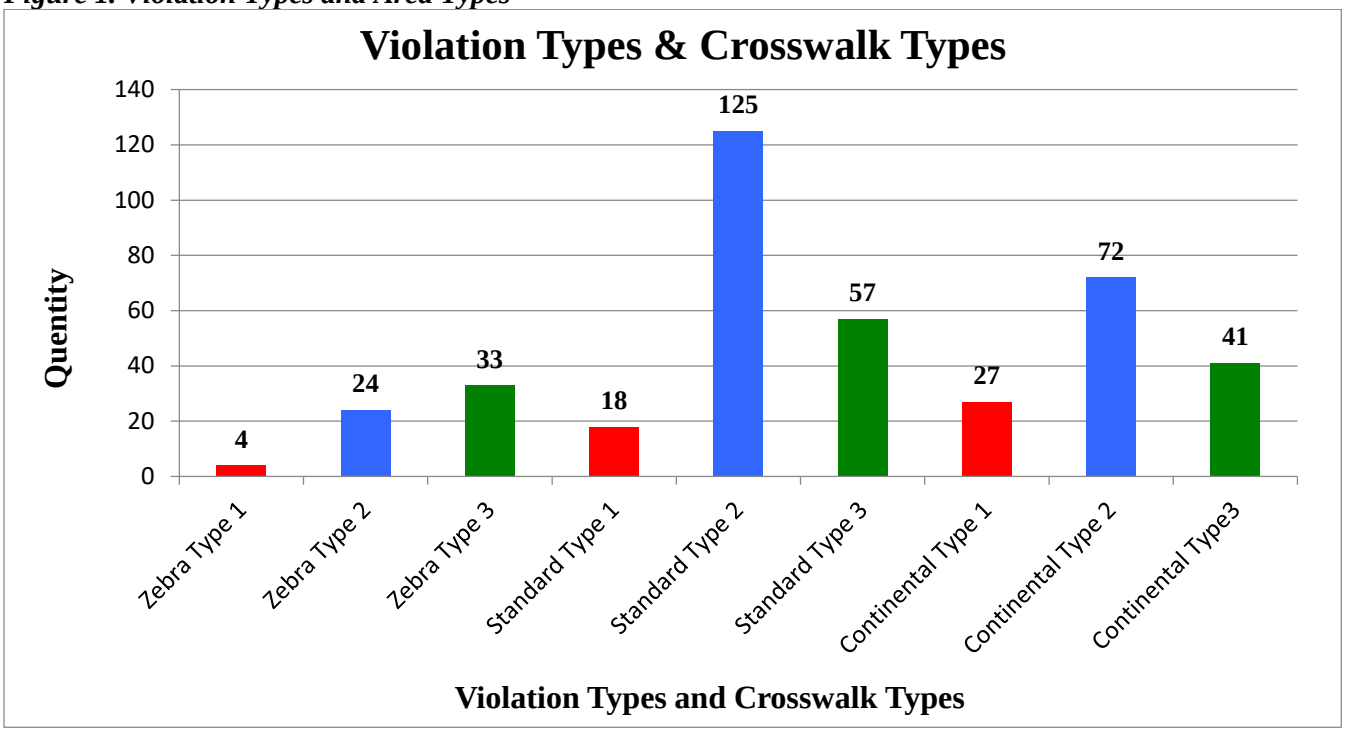


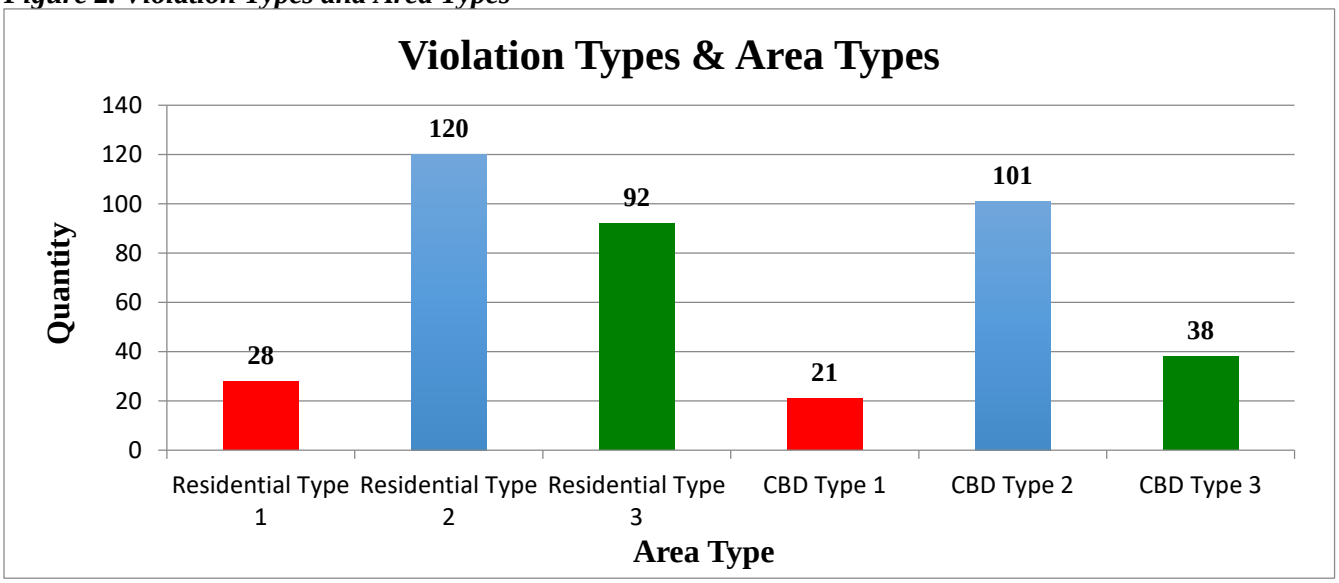
Table 4 illustrates Violation Types and number of Lanes that the pedestrian is crossing. It has been shown before that one-unit change in the variable "lane", the log of the ratio of the two probabilities will be decreased. As an example, the ratio of the vehicles that commit Violation Type 3 over Violation Type 1 in a 10-lane street is $\frac{3}{7}$ = 0.43. The ratio of the vehicles that commit Violation Type 3 over Violation Type 1 in a 3-lane and 5-lane street are $\frac{27}{1}$ = 27. Generally, in this study as the number of lanes that the pedestrian is crossing increases, the likelihood of committing Violation Type 1 over Violation Type 3 increases.

Table 4. Violation Types and Number of Lanes that the Pedestrian is Crossing

Number of Lanes that the Pedestrian is Crossing	Violation Type 1	Violation Type 2	Violation Type 3	Total
3	1	12	27	40
5	22	85	73	180
6	1	14	5	20
7	16	65	19	100
9	2	15	3	20
10	7	30	3	40
Total	49	221	130	400

Figure 2 illustrates Violation Types and Area Types. The ratio of the vehicles that commit Violation Type 3 over Violation Type 1 in "residential" area is $\frac{92}{28}$ = 3.28. The ratio of the vehicles that commit Violation Type 3 over Violation Type 1 in "CBD" area is $\frac{38}{21}$ = 1.3. Therefore, in this study, the vehicles are more likely to commit Violation Type 3 over Violation Type 1 in "residential" area comparing with the baseline, which is "CBD" area.

Figure 2. Violation Types and Area Types



CONCLUSIONS AND RECOMMENDATIONS

In this study, it was concluded that “females” are more likely to commit Violation Type 2 and Type 3 than Violation Type 1, comparing with the “male”, which was assigned as the baseline category. Generally, it was determined that “females” seem to act more cautiously and “males” tend to act more aggressively when making the right-turn. It was found that “vans” are more likely to commit Violation Type 1 than Type 2 comparing with “coupes”. Also, it was discovered that drivers are more likely to commit Violation Type 2 than Type 1 in intersections with “standard” crosswalks, comparing with intersections with “continental” crosswalks. Additionally, drivers were more prone to commit Violation Type 1 than Type 3 as the number of “lanes” that the pedestrian was crossing increased. Finally, it was observed that drivers commit Violation Type 3 more than Type 1 in “residential” areas than “CBD” areas. Also, these results that were obtained from running a multinomial logistic regression model were verified graphically and algebraically by taking the ratios and making charts. Among the determined significant factors, Driver’s Age and Driver’s Gender were the most significant factors since their p-values were the smallest. It can be concluded that generally, human factors might play a significant role in right-turn behavior, following by environmental factors and vehicle features. Some treatments that can be recommended in order to minimize the occurrence of Violation Type 1 and enhance pedestrian safety at signalized intersection is implementation of exclusive pedestrian phase if feasible, and utilization of protected-right turn at intersections. Providing exclusive pedestrian phase would allow pedestrians to cross any leg of the intersection when traffic is stopped on all approaches. Also, providing protected right-turn would allow the vehicles to make the right-turn without any conflict to crossing pedestrians. California Vehicle Code does not document the Right-turn Scenario 1 as a violation type. As stated before, Right-turn Scenario 1 is a dangerous situation since the pedestrian is at risk of collision. It is recommended that Right-turn Scenario 1 will be considered to be recorded in the C.V.C as a violation type in order to minimize the occurrence of such scenarios and improve safety. By doing so, Right-turn Scenario 1 can also be addressed in the California Driver’s Handbook as a violation type.

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