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Source: *Journal of the Transportation Research Forum*, Vol. 50, No. 1 (Spring 2011), pp. 5-17
Published by: Transportation Research Forum
Stable URL: http://www.trforum.org/journal

Safety Analysis of Continuous Green Through Lane Intersections

by Thobias Sando, Deo Chimba, Valerian Kwigizile and Holly Walker

This paper examines safety characteristics of continuous green through lane (CGTL) intersections using paired-t test and ordered probit (OP) statistical models. The results suggest that there is a significant difference between the proportions of sideswipe crashes in the CGTL direction compared with the opposite direction. However, the results did not suggest a significant difference between the proportions of rear-end and right-angle crashes for the CGTL and normal directions. The results further suggest that angle crashes and crashes involving lane changing maneuvers are significantly more severe compared with rear-end crashes.

INTRODUCTION

Escalating traffic demands on urban roadways have caused traffic engineers to use various measures to reduce congestion, especially at signalized intersections. Transportation agencies are using unconventional measures where conventional measures have been exhausted. One unconventional low cost design strategy used in parts of Florida is the installation of continuous green through lanes (CGTLs). These lanes are used to reduce increasing demand for longer green times for through movement at intersections with considerably higher through volumes. CGTLs are "T" intersections with one or two through lanes on the mainline leg receiving a continuous green indication, i.e., passing without stopping, while the inside through lane(s) in the same direction receive conventional green, yellow, and red indications (Figure 1). Installation of CGTLs is less costly than intersection widening alternatives, hence in most cases they provide a cost effective solution for handling high through traffic at T-intersections.

Figure 1: An Example of CGTL Intersection

Although CGTLs have been used for more than three decades in Florida and their operational benefits are evident, they are still considered a relatively new design alternative which many agencies are reluctant to approve. There have been mixed reviews of the suitability and effectiveness of CGTL intersections in Jacksonville, Florida. This is because citizens feel they are not safe, especially for motorists unfamiliar with their design, and this has led to their removal from several locations while new ones continue to be installed in other locations. This study evaluates different crash patterns that occur at CGTLs and further analyzes the influence of roadway, traffic, driver, and environmental conditions on injury severity for different crash patterns.

The rest of the paper is organized as follows: The next section provides a summary of the literature on the analysis of crash patterns at intersections. It is followed by a methodology section which outlines the analytical techniques used in this study. The methodology section is followed by the results where the findings are discussed and explanations offered for them. The final section of the paper presents the conclusions and recommendation.

LITERATURE REVIEW

Many previous studies have evaluated crash patterns at signalized intersections. Wang and Abdel-Aty (2008) evaluated left-turn crashes occurring at 197 four-legged signalized intersections (intersections connecting four roadway segments) in Florida and found that traffic flows, the width of the crossing distance and signal phasing, affect left-turn crashes. Mitra et al. (2002) studied right-angled and rear-end crashes by maneuver type at four-legged signalized intersections in Singapore. The results indicated that the presence of uncontrolled left-turn channels, wider medians, higher approach volumes, and an increase in signal phase are the most important factors that increase accidents from both types of maneuvers. In an attempt to develop expected conflict value tables for unsignalized three-legged intersections, Weerasuriya and Pietrzyk (1998) modeled conflict types at unsignalized three-legged intersections. They divided conflicts into three main groups: same direction, opposing direction, and cross traffic conflicts, which were further subdivided into 12 crash categories. Traffic conflicts increased as the number of lanes increased. For example, they observed an average of about 70 rear-end conflicts on three-legged 2 x 6 intersections with six lanes in the major street and two lanes in the minor street. About 20 rear-end conflicts on average were observed for three-legged 2 x 2 (two lanes for minor street and two lanes for major street) and 2 x 4 intersections, i.e., intersections with two lanes for minor street and four lanes for major street. Persaud and Nguyen (1998) developed safety performance models for four-legged intersections based on 25 specific crash patterns, which were defined by the movements of the accident vehicles prior to collisions. Out of the 25 patterns, the leading three patterns in property damage only crashes in the order of importance were rear-end, left-turn versus opposing through traffic, and right-angle crashes. Additionally, the proportion of crashes that involved left-turn versus opposing through traffic was the highest, followed by right-angle and rear-end crashes among severe crashes.

Whereas there is a growing body of research about modeling intersection crash data and crash patterns in particular, there is still a lack of an overall picture of the safety characteristics of CGTL intersections, particularly crash patterns. The literature on the safety of CGTLs is limited. Hummer and Boone (1995) investigated possible gains in travel efficiency from three unconventional strategies, including median U-turn, two different CGTLs, and the North Carolina bowtie intersection. The Florida and North Carolina versions of the CGTLs provided substantial reductions in travel time and stops for through volumes less than 700 vehicles per hour per lane. Jarem (2004) evaluated the safety and cost-and-benefit ratios of five CGTL intersections in Orlando, Florida, and found that crashes related to CGTLs ranged from 8% to 24% for the five intersections that were investigated. Most of the crashes were rear-end caused by unexpected stopping of vehicles in the CGTLs followed by sideswipe crashes caused by erratic lane changes of vehicles from non-CGTLs to avoid a red light. Few crashes involved left-turn vehicles encroaching on CGTLs, and each of the five intersections had a different magnitude of each type of crash related to the CGTL.

Although the levels of CGTL related crashes reported by Jarem (2004) differ for the intersections that were investigated, he does not study the influence of site characteristics on the occurrence of different types of crashes at CGTLs. The study reported herein was conducted on all CGTLs in Jacksonville with the purpose of quantifying the effects of site characteristics on the safety of CGTL intersections.

METHODOLOGY

Data

At the beginning of this study, the city of Jacksonville had a total of 17 known CGTL intersections. Eight of them (shaded intersections in Table 1) have been converted to traditional intersection configurations or have had major maintenance or construction work done between 2003 and 2008 and were not considered in this study, leaving only nine (sites one though nine in Table 1) to be studied. Several data sources, including drawings, condition diagrams, intersection photos, aerial photographs, and straight line diagrams, were used to examine differences in site characteristics between the intersections. These sources together with field visits were used to collect data on intersection characteristics such as configurations, land use proximity and location of driveways, signs and pavement markings, and number of CGTLs.

Table 1: List of CGTL Intersections in Jacksonville, Florida

No.	Intersection	Install Date	Removal Date
1	US 17 @ Ortega Forest Dr.	2/3/1987	-
2	US 17 @ Entrance to Roosevelt Mall	10/13/1986	-
3	US 17 @ Park Street South	9/29/1983	-
4	US 17 @ Long Bow Rd.	5/1/1972	-
5	US 17 @ Baisden Road	2/1/1991	-
6	US 1 @ 45th Street	10/4/1978	-
7	Normandy @ Country Creek	5/1/1985	-
8	Normandy@ I-295	-	-
9	SR 13 @ Beauclerc Rd.	10/12/1973	-
10	US 17 @ I-295 South	2/23/1972	11/9/2003
11	US 17 @ Plymouth	8/19/1986	10/2/2004
12	A1A @ Marlin Street	3/1/1987	4/15/2002
13	A1A @ Ponte Vedra Lakes Blvd.	5/1/1987	5/2/2002
14	US 17 @ I-295 North	11/16/1995	-
15	US 17 @ Heckscher Drive	2/1/1987	-
16	US 17 @ Emerson Park Blvd.	5/17/1992	-
17	US 17 @ US 19	3/26/1992	-

Table 2 summarizes the characteristics of the nine sites, including driveway code, number of CGTLs, and separator type. Categorical values were used to describe differences in these three basic site characteristics. For driveways, a zero code represents absence of driveways within 250 feet of an intersection, one represents intersections which do not have driveways in a non-CGTL direction, and, two, intersections which do not have driveways in the CGTL direction. As far as the number of continuous green through lanes are concerned, intersections with one CGTL are coded as one while those with two CGTLs are coded as two. Three main methods were used to separate continuous green traffic from other movements. These are double white lines (coded as a zero), raised rounded domes (coded as one), and raised curbs (coded as two). These methods help motorists identify the special use of CGTLs, provide a buffer between vehicles making left turns from minor roads and vehicles in the CGTL, and discourage swerving from adjacent lanes as drivers tend to avoid being stopped by a red light.

Table 2: Basic Site Characteristics

Site Characteristic	Intersection Number*								
	1	2	3	4	5	6	7	8	9
Driveway code	0	1	0	0	0	0	2	0	1
Number of CGGLs	2	2	2	2	1	2	1	1	2
Separator type	0	0	0	0	0	1	0	2	0

*Intersection numbers (1 through 9) are in the order presented in Table 1.

Crash data were collected from the Florida Department of Transportation (FDOT) database known as the Crash Analysis Reporting (CAR) System. The data are for 398 crashes that occurred at nine CGTL intersections from 2003 to 2008. The data categorize the degree of injury severity as none, possible, non-incapacitating, incapacitating, and fatal. Generally, possible injury and non-incapacitating injuries represent the same injury severity level, i.e., non-incapacitating injury. Therefore, they were combined giving a total of four levels of injury severity. Other variables are site characteristics, traffic, and environmental conditions at the time of the crash. The site characteristics included whether or not the crash involved vehicles using CGTL traffic lanes, the number of CGTLs, and if there is a driveway in the vicinity of the intersection. The environmental conditions are weather and lighting. Speed limit and annual average daily traffic (AADT) are the traffic factors. Other factors considered are driver age, number of vehicles involved in the accident, and time of day. All crashes that occurred within 250 feet of the study intersection were assumed to be influenced by the intersections. The crashes were further screened by examining crash diagrams to remove those that were not intersection related but within 250 feet of the intersection. Table 3 shows a description of each variable used in the model.

Analytical Techniques

Three methods were used in this study to analyze the data. The first is proportions analysis, which uses simple percentage calculations to examine crash patterns at CGTLs. The second is comparative analysis to determine if there is any underrepresentation or overrepresentation of some crash patterns on CGTL, and the third method is the ordered probit (OP) model, which was used to model injury severity.

In the comparative analysis, four distinct conflict types are analyzed. They are those due to lane changes (pattern one versus pattern 10), rear-end crashes (patterns two and three versus pattern six), angle crashes involving left-turning traffic from a minor street (patterns four and five versus pattern seven), and other crashes. For each conflict pattern, the proportion of the total intersection crashes for the CGTL direction was compared with the proportion in the non-CGTL direction using a paired-*t* test. This test is appropriate in analyzing samples which have two different treatments, i.e., paired treatments. In this case, every intersection has two treatments at each mainline direction: installation of continuous green through lanes (in the CGTL direction) and normal lanes (in the non-CGTL direction). This method provides the statistic which is used to determine if there is a significant difference between the proportion means for the CGTL and non-CGTL directions. The null hypothesis is that the proportions of the aforementioned three conflict types are equal for the CGTL and non-CGTL directions, while the alternative hypothesis is that the proportions of the conflict types are not equal for the CGTL and non-CGTL directions. The alternative hypothesis is accepted only when the data suggest sufficient evidence to support it, hence rejecting the null hypothesis. All conflict types were tested at the 95% confidence level.

Table 3: Description of the Model Variables

Explanatory Variables	Categories	Explanation
Injury Severity	0	No injury
	1	Non-incapacitating injury
	2	Incapacitating injury
	3	Fatal
Crash Conflict Group	0	Rear-end (patterns 2, 6, and 9)
	1	Angle (patterns 4, 5, and 7)
	2	Lane-change (patterns 1 and 10)
	3	Left-turn (patterns 8 and 11)
	4	All other
On CGTL	0	Not involving vehicles on CGTL
	1	Involving vehicles on CGTL
Number of CGTL	0	One CGTL
	1	Two CGTLs
Driveway	0	No driveways
	1	Driveways on normal direction
	2	Driveways on CGTL direction
Separator Type	0	Double white lines
	1	Rounded domes
	2	Raised concrete curb
Lighting	0	Daylight
	1	Dark
Weather	0	Clear and cloudy
	1	Rainy
Time of day	0	Early morning/Late at night (midnight to 6:00 am)
	1	Morning (6:00 am to noon)
	2	Afternoon (noon to 6:00 pm)
	3	Evening (6:00 pm to midnight)
Speed limit	0	45 mph
	1	50 mph
Age (years)	0	<=25
	1	25 to 64
	2	>=65
Number of vehicles	Continuous variable	
Annual Average Daily Traffic (AADT)	Continuous variable	

An ordered probit (OP) model was used because injury severity is ordered, i.e., from no injury (property damage only), possible injury, non-incapacitating injury, incapacitating injury and killed. Several previous studies have used this method in modeling injury severity (Quddus et al. 2002, Kockelman and Kweon 2002, Abdel-Aty 2003, Abdel-Aty and Keller 2005). Because the injury data used in this study are categorical, the use of OP is appropriate as it requires no assumptions regarding the ordinal nature of the dependent variable (Quddus 2002). The OP model for four categories of injury severity is given in the following form (Kockelman 2002, Washington et al. 2003):

$$(1)\quad q_k = \begin{cases} 0 \quad \text{if } -\infty \le q_n \le \mu_1 \text{ (no injury)} \\ 1 \quad \text{if } \mu_1 \le q_n \le \mu_2 \text{ (non-incapacitating injury)} \\ 2 \quad \text{if } \mu_2 \le q_n \le \mu_3 \text{ (incapacitating injury)} \\ 3 \quad \text{if } \mu_3 \le q_n \le \mu_4 \text{ (fatal)} \end{cases}$$

Where q_n is the observed injury severity (coded as a categorical variable), and μ_i values are the thresholds (cutoffs) that define each q_n. The probabilities associated with ordinal outcomes of an OP model are calculated as:

$$(2)\quad P_n(k) = \varphi\left(\mu_{k+1} - \beta z_n\right) - \varphi\left(\mu_k - \beta z_n\right)$$

Where φ is the standard normal cumulative density function, β is the vector of estimated parameters, and z a vector of model variables. Predictions from the OP models are done by considering the thresholds and comparing the predicted probability with the given cutoff probability boundaries and then classifying injuries based on the cutoffs.

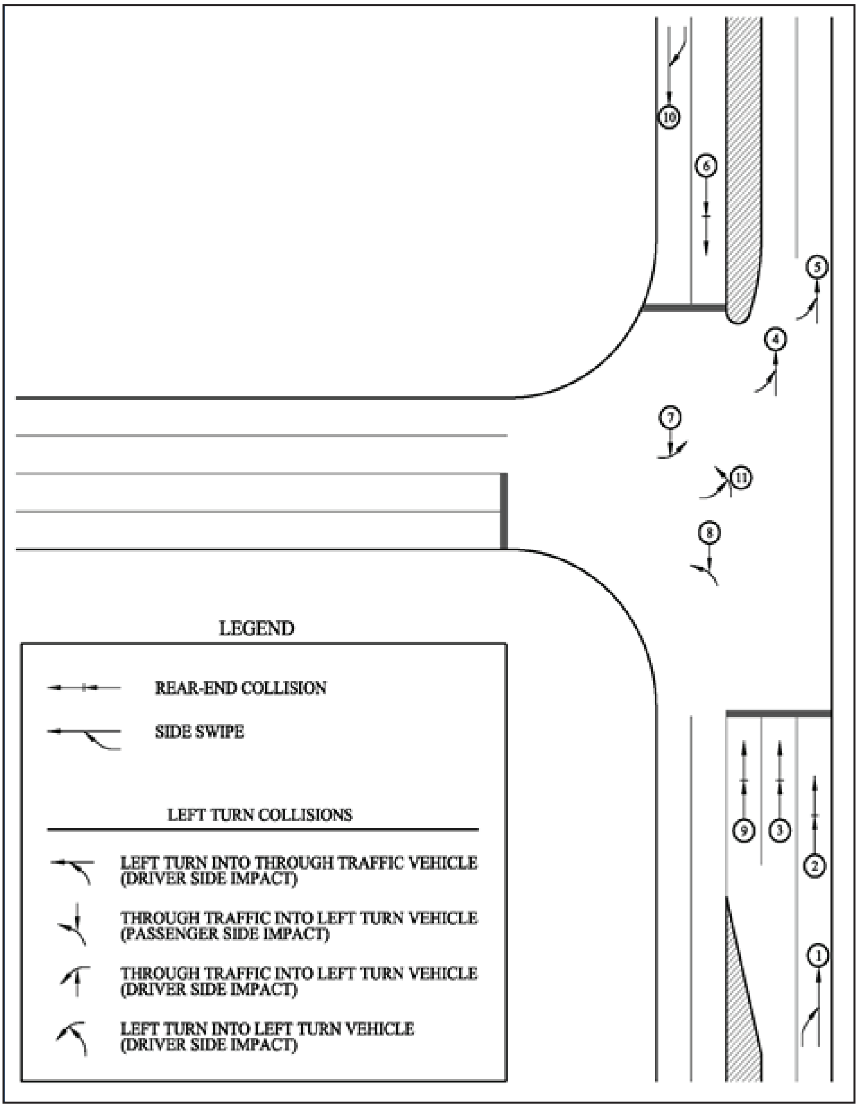
RESULTS

Crash Pattern

This analysis involved careful examinations of crash diagrams to determine distinct crash patterns. After reviewing crash diagrams and narratives in crash reports, crashes were classified into the 11 distinct patterns shown in Figure 2. Crashes that did not fall into the 11 patterns shown in Figure 2 were combined into pattern 12 as shown in Table 4. This table shows a summary of the percentages of each of the 12 crash patterns for each intersection. Most of the crashes in pattern 12 occurred on the side street (minor street direction) while few involved vehicles in the major street. Some crash types in pattern 12 include rear-end and right-turning crashes from the minor street, run-off the road crashes, pedestrian crashes, and collisions with vehicles from driveways. These crashes were combined into one group and included in the comparative analysis.

The data in Table 4 also show that there are more crashes involving lane changing in the CGTL direction (conflict pattern one) compared with the direction which has traditional through lanes (conflict pattern 10). Approximately 6.01% of the crashes involved vehicles changing lanes in the CGTL direction while only 1.78% involved lane changing vehicles in the traditional through lanes. The percentages of rear end crashes for both traditional through lanes direction (pattern six) and the CGTL direction (patterns two and three) appear to be approximately equal (23.60% for continuous through lanes and 23.39% for traditional through lanes). A thorough examination of the crash diagrams and police report narratives revealed that rear end crashes on the traditional lanes involved through and right-turning vehicles, mostly caused by right-turning vehicles reducing speed to perform a right turning maneuver. Crash patterns two and three, which represent rear-end crashes in the CGTL direction, were mostly caused by motorists who unexpectedly stopped in the CGTL.

Figure 2: CGTL Intersection Crash Patterns Classified by Conflict Types



Conflict categories four and five represent right angle crashes involving left-turning vehicles from the minor street and vehicles crossing the intersection from the CGTL direction. The difference between these two categories is that conflict category four involves right angle crashes with drivers who are in the non-continuous lane while category five is for right angle collisions that occur on the CGTL. The main causes of conflict category five crashes are the motorists in the non-continuous lane who are supposed to stop on red but inattentively cross the intersection by assuming that the continuous green arrow applies to their lane. Conversely, conflict category five crashes are caused by left-turning vehicles veering into the CGTL, disregarding lane separation markers. It is observed from the data in Table 4 that there were no crashes caused by crash conflict pattern five at intersection eight (Normandy at I-295) due to the use of a curb to separate continuous green through movements from other movements. Also, there were no crashes caused by conflict pattern one (lane changing from normal lane to CGTL to avoid stopping at intersection) because the separation curb is extended to both sides of the intersection.

Table 4: Proportions of Crashes by Pattern Type for Each Intersection in the Study

Conflict Pattern	Conflict Description	1	2	3	4	5	6	7	8	9	Average
1	Sideswipe between non-CGTL and CGTL through traffic	5.88%	9.52%	6.56%	7.89%	0.00%	5.41%	17.14%	0.00%	7.14%	6.01%
2	Rear-end on CGTL	33.33%	0.00%	0.00%	21.05%	11.76%	13.51%	11.43%	3.08%	12.50%	14.25%
3	Rear-end on non-CGTL	11.76%	14.29%	3.28%	10.53%	5.88%	8.11%	2.86%	6.15%	19.64%	9.35%
4	Angle collision between left-turn minor street and non-CGTL through traffic	1.96%	0.00%	4.92%	0.00%	0.00%	0.00%	0.00%	0.00%	5.36%	1.78%
5	Angle collision between left-turn minor street and CGTL through traffic	1.96%	0.00%	3.28%	5.26%	11.76%	8.11%	11.43%	0.00%	7.14%	4.68%
6	Rear-end on conventional approach	17.65%	38.10%	16.39%	18.42%	11.76%	18.92%	5.71%	50.77%	28.57%	23.39%
7	Right-angle collision between through traffic from conventional approach and left-turn traffic from minor street	13.73%	14.29%	0.00%	7.89%	8.82%	2.70%	0.00%	4.62%	5.36%	6.68%
8	Angle collision between through traffic from conventional approach and left-turn traffic from CGTL approach	0.00%	9.52%	1.64%	5.26%	8.82%	5.41%	2.86%	6.15%	7.14%	4.23%
9	Rear-end collision on left turn lane	0.00%	4.76%	0.00%	0.00%	2.94%	2.70%	2.86%	6.15%	1.79%	2.00%
10	Sideswipe on conventional approach	0.00%	4.76%	1.64%	2.63%	0.00%	0.00%	2.86%	6.15%	0.00%	1.78%
11	Angle collision between left turn traffic from minor and major streets	0.00%	0.00%	1.64%	0.00%	2.94%	0.00%	34.29%	0.00%	0.00%	3.12%
12	All other conflict patterns not represented by categories 1 through 11	13.73%	4.76%	60.66%	21.05%	35.29%	35.14%	8.57%	17.92%	5.36%	22.72%

*Intersection numbers (1 through 9) are in the order presented in Table 1.

Comparative Analysis

The data show that there are more crashes from lane changing maneuvers in the CGTL direction (pattern one) than in the non-CGTL direction (pattern 10). The results in Table 5 indicate that there is a significant difference between the proportions of lane changing crashes in the CGTL and non-CGTL directions (*p*-value = 0.038) at the 95% confidence level. The high proportion of lane changing crashes might be due to motorists who suddenly swerve to the CGTLs to avoid being stopped by the red light on non-CGTLs. The data suggest a slightly higher average proportion of rear-end crashes in the non-CGTL direction (0.256% of all crashes) than in the CGTL direction (0.229% of all crashes). Rear-end crashes on CGTLs are most probably caused by motorists who are unfamiliar with how the CGTLs operate and who unexpectedly stop in the CGTL by mistakenly observing a red light meant for non-CGTLs. However, the results in the table show that this difference is not significant at the 95% confidence level (*p*-value = 0.736). The observed average proportion of right-angle crashes involving left-turns from the minor street and vehicles in the CGTL direction was slightly higher (0.074) than for the non-CGTL direction (0.071). The crash diagrams revealed that right-angle crashes involving CGTLs are mostly caused by motorists turning left from the minor street and veering into the CGTLs instead of turning to the non-CGTLs. Furthermore, Table 5 shows there is no significant difference in the observed proportions of angle crashes (patterns four, five, and seven) between CGTL and non-CGTL directions.

Table 5: Comparative Analysis Results

Conflict type	Direction	Proportion mean	Standard Deviation	Degrees of freedom	*t*-value	p-value	Reject null?
Lane changing	CGTL	0.072	0.055	8	2.475	0.038	yes
	Non-CGTL	0.023	0.027				
Rear-ending	CGTL	0.229	0.135	8	-0.350	0.736	No
	Non-CGTL	0.256	0.164				
Angle	CGTL	0.074	0.053	8	0.102	0.321	No
	Non-CGTL	0.071	0.059				

Injury Severity at CGTL Intersection Crashes

The STATA statistical package was used for the ordered probit model runs. Two injury severity models were estimated as in Abdel-Aty and Keller (2005). The first describes the relationship between injury severity with different crash conflict patterns while the second explains the relationship between injury severity and intersection characteristics, environmental conditions, and traffic characteristics. Table 6 shows the coefficients of the first model. The results indicate that right-angle crashes (crash conflict group one) and lane changing crashes (crash conflict group two) are significant predictors of injury severity at CGTL intersections. The level of injury severity is higher for conflict categories one and two compared with rear-end crashes (crash conflict group zero in Table 3).

Table 6: Ordered Probit Model for Crash Conflict Groups

Variable	Coefficient	Standard Error	Z	P>z
Involving Continuous Green Through Lane Traffic	0.2096	0.2135	0.98	0.326
Crash Conflict Group				
Angle (patterns 4, 5, and 7)	0.4796	0.2401	2.10	0.036
Lane-change (patterns 1 and 10)	0.5035	0.3038	1.99	0.046
Left-turn (patterns 8 and 11)	0.4416	0.3385	1.31	0.192
All other	-7.2223	0.0000	0	1
Thresholds				
μ_1	-0.1312	0.1054		
μ_2	0.6819	0.1087		
μ_3	1.4721	0.1274		
μ_4	2.3822	0.2086		

The results of the second model in Table 7 indicate crashes that take place during the time categories of 6:00 a.m. in the morning to noon and noon to 6:00 p.m. result in lower injury severity. The results also suggest that drivers 65 years and older have higher injury severity levels. Also, as the table shows, all the other variables in the model had statistically insignificant coefficients. These include speed limit, rounded domes, raised concrete curbs, number of vehicles, and annual average daily traffic.

CONCLUSIONS AND RECOMMENDATIONS

This study was conducted to examine the safety characteristics of unconventional continuous green through lanes at nine sites in Jacksonville, Florida. A thorough review of crash data resulted in 11 distinct crash conflict patterns that were used to examine the influence of CGTLs on the safety characteristics of the study intersections. Three analysis methods were used: general proportions analysis, comparative analysis, and injury severity ordered probit modeling. Based on the proportions analysis, there are three common types of crashes that involve CGTL traffic: (1) sideswipe crashes caused by motorists weaving from adjacent through lanes to avoid having to stop for the red signal indication, (2) angle crashes caused by motorists turning left from a minor street and swerving into the CGTL by disregarding the “do not change lane” barriers such as double white lines and rounded domes, and (3) rear-end crashes caused by motorists who unexpectedly stop in the CGTL. The results of the proportions analysis show that on average the proportion of sideswipe crashes in the CGTL was 6.01% (conflict pattern one) compared with 1.78% in the opposite direction (conflict pattern 10). Also, on average, 4.68% of all crashes were caused by left-turning vehicles from the minor direction (conflict pattern five) crossing to the CGTLs. Typically, conflict pattern five is caused by inattentive drivers or motorists who are not familiar with the presence of CGTL. It is also worth mentioning that on average there were more rear-end crashes on continuous green through lanes (conflict pattern two, 14.25%) compared with normal lanes (conflict pattern 3, 9.35%).

The results of the comparative analysis which employed a paired t-test indicate that there is a significant difference between the proportions of sideswipe crashes in the CGTL direction compared with the opposite direction. On the other hand, the paired-t test results did not suggest a significant difference between the proportions of rear-end and right-angle crashes for the CGTL and normal directions.

Table 7: Injury Severity Results Based on Site and Traffic Characteristics and Environmental Conditions

Variable	Coefficient	Standard Error	Z	P>z
Annual average daily traffic	1.8E-05	0.0000	1.43	0.152
Number of continuous green through lanes	0.2852	0.3187	0.9	0.371
Number of vehicles	0.0727	0.1482	0.49	0.624
Traffic Involved				
Involving vehicles on CGTL	-0.2008	0.2258	-0.89	0.374
Presence of driveways				
Driveways on normal direction	-0.1636	0.3536	-0.46	0.644
Driveways on CGTL direction	-0.3025	0.5080	-0.6	0.552
Separator type				
Rounded domes	0.3887	0.5293	0.73	0.463
Raised concrete curb	0.2079	0.5741	0.36	0.717
Lighting				
Dark	0.4913	0.4173	1.18	0.239
Weather				
Rainy	-0.3694	0.5263	-0.7	0.483
Time of day				
Morning (6:00 am to noon)	-0.9012	0.4577	-1.97	0.049
Afternoon (noon to 6:00 pm)	-0.8451	0.3395	-2.49	0.013
Evening (6:00 pm to midnight)	-0.5480	0.4598	-1.19	0.233
Speed Limit				
50 mph	0.1241	0.3955	0.31	0.754
Age (years)				
25 to 64	0.4094	0.2277	1.8	0.072
>=65	0.8517	0.3399	2.63	0.012
Thresholds				
μ_1	-1.8869	0.5142		
μ_2	0.7630	0.4335		
μ_3	1.5785	0.4359		
μ_4	2.3698	0.4400		

Two different ordered probit models were developed: one based on crash pattern types and another considering site conditions, environmental factors, and traffic conditions. The results of the first model indicate that angle crashes and crashes involving lane changing maneuvers are significantly more severe than rear-end crashes. For the second model, only time of day and age of driver were found to be significant in predicting injury severity level. Lower injury severity was observed for crashes that occurred during the day, i.e., between 6:00 a.m. and 6:00 p.m. Crashes that involved drivers who were 65 years or older had higher injury severity level.

Based on the observations of this study, the following design features are recommended as they may improve the safety of CGTL intersections: advance warning signs and highly visible raised separators. Advance warning signs provide guidance to motorists as to the purpose of the continuous through lanes and lane use instructions. This is particularly helpful to non-commuters who are not familiar with continuous green through lanes. Providing highly visible raised separators, in lieu of double white lines and raised rounded domes, creates a distinct separation between the continuous through traffic and the adjacent lanes. This separation will prevent lane changing caused by motorists crossing the double white lines.

Further research is needed to study the influence of the factors which were not included in this study, such as type of left-turn restrictions (protected versus permitted), downstream and upstream traffic conditions, advance warning signage, and typical driver population, among other factors. Efforts are underway to conduct a comparative analysis between CGTL intersections and traditional "T" intersections. There are also plans to increase the dataset to include CGTL intersections in other parts of Florida. It is recommended that some specific site characteristics such as signage and lane markings, left-turning restrictions, and other pertinent variables be included in the analysis. Finally, because the study used one locality, further studies of similar intersections elsewhere are required to permit generalizations of the results in this paper.

References

Abdel-Aty, M. and J. Keller. "Exploring the Overall and Specific Crash Severity Levels at Signalized Intersections." *Accident Analysis and Prevention* 37, (2005): 417–425.

Abdel-Aty. M. "Analysis of Driver Injury Severity Levels at Multiple Locations Using Ordered Probit Models." *Journal of Safety Research* 34, (2003): 597– 603.

Hummer, J.E. and J.L. Boone. "Travel Efficiency of Unconventional Suburban Arterial Intersection Designs." *Transportation Research Record: Journal of the Transportation Research Board* 1500, (1995): 153-161.

Jarem, E.S. "Safety and Operational Characteristics of Continuous Green Through Lanes at Signalized Intersections in Florida." Presented at ITE Annual Meeting and Exhibit, Orlando, FL, August 2004.

Kockelman, K.M. and Y. Kweon. "Driver Injury Severity: An Application of Ordered Probit Models." *Accident Analysis and Prevention* 34, (2002): 313–321.

Mitra, S., H.C. Chin and M.A. Quddus. "Study of Intersection Accidents by Maneuver Type." *Transportation Research Record: Journal of the Transportation Research Board* 1784, (2002): 43-50.

Persaud, B. and T. Nguyen. "Dissagregate Safety Performance Models for Signalized Intersections on Ontario Provincial Roads." *Transportation Research Record: Journal of the Transportation Research Board* 1635, (1998): 113-120.

Quddus, M.A., R.B. Noland and H.C. Chin. "An Analysis of Motorcycle Injury and Vehicle Damage Severity Using Ordered Probit Models." *Journal of Safety Research* 33, (2002): 445– 462.

Wang, X. and M. Abdel-Aty. "Analysis of Left-turn Crash Injury Severity by Conflicting Pattern Using Partial Proportional Odds Models." *Accident Analysis and Prevention* 40, (2008): 1674–1682.

Washington. S.P., M.G. Karlaftis, and F. L. Mannering. *Statistical and Econometric Methods for Transportation Data Analysis*. Chapman & Hall/CRC, Florida, 2003.

Weerasuriya, S.A. and M.C. Pietrzyk. “Development of Expected Conflict Value Tables for Unsignalized Three-Legged Intersections.” *Transportation Research Record: Journal of the Transportation Research Board* 1635, (1998): 121-126.

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