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Safety evaluation of continuous green T intersections: A propensity scores-genetic matching-potential outcomes approach

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ABSTRACT

The continuous green T intersection is characterized by a channelized left-turn movement from the minor street approach onto the major street, along with a continuous through movement on the major street. The continuous flow through movement is not controlled by the three-phase traffic signal that is used to separate all other movements at the intersection. Rather, the continuous through movement typically has a green through arrow indicator to inform drivers that they do not have to stop. Past research has consistently shown that there are operational and environmental benefits to implementing this intersection form at three-leg locations, when compared to a conventional signalized intersection. These benefits include reduced delay, fuel consumption, and emissions. The safety effects of the conventional green T intersection are less clear. Past research has been limited to small sample sizes, or utilized only statistical comparisons reported crashes to evaluate the safety performance relative to similar intersection types. The present study overcomes past safety research evaluations by using a propensity scores-potential outcomes framework, with genetic matching, to compare the safety performance of the continuous green T to conventional signalized intersections, using treatment and comparison site data from Florida and South Carolina. The results show that the expected total, fatal and injury, and target crash (rear-end, angle, and sideswipe) frequencies are lower at the continuous green T intersection relative to the conventional signalized intersection (CMFs of 0.958 [95% CI = 0.772–1.189], 0.846 [95% CI = 0.651–1.099], and 0.920 [95% CI = 0.714–1.185], respectively).

1. Introduction

At-grade intersections are an inherent conflict location on the highway and street network as the turning or crossing paths of motorized and non-motorized users frequently interact at these locations. As a result, crashes involving both user groups often occur at intersections. The Federal Highway Administration (FHWA) estimates that, on average, 26 percent of fatal and 50 percent of injury crashes in the United States (U.S.) occur at intersections. National Cooperative Highway Research Program (NCHRP) *Report 500, Volume 12: A Guide for Reducing Collisions at Signalized Intersections* estimated that approximately 30 percent of fatal intersection crashes occur at locations with signalized control (Antonucci et al., 2004). Intersection safety is a priority among transportation agencies in the U.S.

Alternative intersection designs have emerged in recent years to improve traffic operations and safety. Implementation of specific alternative intersection forms is dependent on the conditions present at the location of interest. The presence of traffic congestion, high crash frequencies or severe crash outcomes at existing intersections often necessitates either operational or safety improvements. Rather than seeking traditional traffic measures to mitigate delay or traffic safety problems, practitioners are now seeking opportunities to convert conventional intersections into alternative, innovative forms. Examples of alternative intersections include the displaced left-turn, restricted crossing U-turn, and median U-turn.

Another alternative intersection type that has been employed in several States is the continuous green T (CGT). CGT intersections are an alternative to conventional signalized intersections. CGT intersections are characterized by a channelized left-turn movement from the minor street approach onto the mainline (major street), along with a continuous mainline through movement that occurs at the same time (Hughes et al., 2010). The continuous-moving through lane (s) are not controlled by a traffic signal phase, while the other intersection movements are controlled by a three-phase

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Fig. 1. Aerial view of CGT intersection (Latitude: 32.240866; Longitude: −80.816626).

signal. The traffic turning left from the minor street onto the mainline do so via an auxiliary lane (i.e., receiving lane), and then merge with the traffic in the continuous flow through lanes. The through lanes on the mainline that have continuous flow typically contain a green through arrow signal indicator to inform drivers that they do not have to stop. The continuous through lanes are often separated from the left-turn and merge lanes with delineators, curbed islands, pavement markings, or other separations. Fig. 1 shows an aerial view of a full CGT intersection. As shown, the lanes at the top of the intersection (traffic is moving from right to left) are the continuous through lanes with a receiving/merging auxiliary lane for the traffic turning left onto the mainline from the minor street. There is also a left-turn lane from the major road onto the minor street. Both auxiliary lanes on the major road are separated from the continuous through lanes by curbed islands and pavement markings.

2. Background

CGT intersections have been used for several decades in Florida. Sando et al. (2011) reported that Florida citizens do not feel that CGT intersections are safe, especially for unfamiliar drivers. For this reason, Sando et al. completed a safety evaluation of the CGT using only data from Florida. The authors' used a paired *t*-test and an ordered probit model to analyze crash type proportions and severity, respectively. The analysis compared crashes that were reported on the continuous through lane on the major CGT roadway, to crashes that were reported on the major road turning lane (i.e., the lane that must stop at the signal). No differences were found in the proportion of rear-end and angle crashes when comparing the two travel lanes (i.e., continuous flow versus signal-controlled travel lane). The continuous flow lanes had a statistically significant higher proportion of sideswipe crashes than the lanes that had to stop. The analysis did not consider the total crash frequency or any potential confounding factors.

The ordered probit model was used to evaluate crash severity outcomes. The severity levels considered in the model included no injury, non-incapacitating injury, incapacitating injury, and fatal. Two ordered probit models were estimated—one model that controlled for crash type and one that controlled for geometric elements, lighting, weather, time of day, speed limit, and driver age. The findings indicated that the continuous flow lane (s) on the CGT major road had lower severity outcomes when controlling for geometrics, lighting, weather, time of day, speed limit, and driver age, when compared to the turning lane on the major road. The opposite finding occurred when only crash type was considered in the model. Neither of these findings, however, was statistically significant.

In a second study using Florida CGT intersection information to evaluate safety, Jarem compiled crash data from five intersections to compare crash rates at each CGT intersection to a critical crash rate (Jarem, 2004). The method to determine the critical crash rate was not provided by the authors; however, this method often involves determining the average crash rate for similar roadway types plus an adjustment for the desired level of statistical confidence, and assumes a linear relationship between reported crashes and traffic volume. The findings from the analysis suggested that the reported crash rates for each of the CGT intersections were lower than the critical crash rates, likely indicating that the CGT intersections did not produce crash rates that exceeded average rates at similar intersections without the continuous green movement. A diagnostic review of the reported crashes at CGT intersections in Florida found that rear-end, sideswipe, and angle crashes were the most common types.

Jarem also completed an analysis of the operational effectiveness of CGT intersections (Jarem, 2004). The analysis considered the five CGT intersections used in the safety analysis, and subsequently performed traffic simulations (using Synchro) to estimate the total delay savings (per vehicle) and total fuel savings achieved by the continuous flow lanes (compared to a standard signalized T intersection). The findings indicated that the CGT intersections resulted in savings of 3.7–28.4 s of delay per vehicle (1601 and 4786 vehicles per hour, respectively) and 0.005–0.015 gallons of fuel saved per vehicle (5275 and 1622 vehicles per hour, respectively). The traffic volumes for the movements other than for the through lanes were not provided.

Litsas and Rakha (2013) provided a more comprehensive operational analysis of CGT intersections. The INTEGRATION simulation software was used to compare CGT to traditional signalized T-intersections (Litsas and Rakha, 2013). The simulation results