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# Quantifying the impact of adaptive traffic control systems on crash frequency and severity: Evidence from Oakland County, Michigan

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ABSTRACT

*Introduction:* Despite seeing widespread usage worldwide, adaptive traffic control systems have experienced relatively little use in the United States. Of the systems used, the Sydney Coordinated Adaptive Traffic System (SCATS) is the most popular in America. Safety benefits of these systems are not as well understood nor as commonly documented. *Method:* This study investigates the safety benefits of adaptive traffic control systems by using the large SCATS-based system in Oakland County, MI known as FAST-TRAC. This study uses data from FAST-TRAC-controlled intersections in Oakland County and compares a wide variety of geometric, traffic, and crash characteristics to similar intersections in metropolitan areas elsewhere in Michigan. Data from 498 signalized intersections are used to conduct a cross-sectional analysis. Negative binomial models are used to estimate models for three dependent crash variables. Multinomial logit models are used to estimate an injury severity model. A variable tracking the presence of FAST-TRAC controllers at intersections is used in all models to determine if a SCATS-based system has an impact on crash occurrences or crash severity. *Results:* Estimates show that the presence of SCATS-based controllers at intersections is likely to reduce angle crashes by up to 19.3%. Severity results show a statistically significant increase in non-serious injuries, but not a significant reduction in incapacitating injuries or fatal accidents.



## 1. Introduction and background

Since its inception, adaptive traffic control system (ATCS) technology has advanced to become a viable method of network-wide traffic management. Systems using this technology have been scrutinized by scientific studies with clear indications of performance improvement over previously used methods (Wolshon & Taylor 1999; Samadi, Rad, Kazemi, & Jafarian 2012). However, the actual usage of ATCS has seen varying levels of support across the globe. Common ATCS systems in place worldwide include SCATS and SCOOT, which are the two most popular systems in use today (Imtech Traffic & Infra UK Ltd 2013; Transport for London. 2013; Zhao & Tian 2012).

Despite these developments internationally, a widespread use of ATCS in the United States has not evolved, which may be contributing to the current traffic control infrastructure unable to effectively manage America's surface road grids. On April 20, 2005, the first National Traffic Signal Report Card was issued by the National Traffic Operations Coalition. This report card graded America's traffic signal infrastructure as a D −. Since 2005, marginal improvement in traffic signal systems operations and management has been recorded, indicated by the D grade released in the 2007 report and the D + grade in the 2012 report (2012 National Traffic Signal Report Card 2012). Perhaps even more telling, the Federal Highway Administration estimates in 2013 that 75% of 260,000 traffic signals in the United States could be improved by updating equipment or by simply adjusting and updating timing plans (FHWA 2013). Is more widespread use of adaptive traffic systems perhaps a solution to this nationwide deficiency? To answer this, we should examine existing ATCS systems viewed locally as successes to determine what lessons we may learn for future ATCS implementations.

One such successful adaptive traffic system is situated in Oakland County, MI, and is also one of the largest ATCS installations in the United States (Zhao & Tian 2012). In the mid-1980s, county officials determined that they would be unable to sustain operations with projected growth demands in the county, and administrators committed to developing a county-wide ITS. Created in 1991, the Faster and Safer Traffic through Routing and Advanced Controls (FAST-TRAC) was first deployed in the Detroit suburb of Troy. The system has grown considerably, now controlling 657 intersections across 17 different cities and townships within the county (Road Commission for Oakland County 2012). Given the age and consistent expansion of the system by county officials, existing studies documenting its performance benefits (Wolshon &

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Taylor 1999), and the extent of coverage of the system, it will be the subject of further scrutiny in this study.

Stevanovic and Zlatkovic (2012) elaborated on the lack of safety evaluations of adaptive traffic control systems, explaining that there is a "lack of interest" in analyzing such systems from a safety-based point of view. The team explained that two major factors are likely: "1) field assessments of safety improvements are impractical (i.e. time consuming and costly), and 2) methods for obtaining safety metrics from microscopic simulation models are uncommon." While there are numerous studies documenting that adaptive systems can outperform time-of-day signal timing methods, very few dive into analyzing the safety benefits of such systems (Sabra 2009). This study aims to offer insight into safety benefits provided by an established adaptive system by examining FAST-TRAC.

## 2. Problem statement

To begin understanding the problems facing Michigan roadways and how adaptive systems may alleviate problems, we must first examine some statistics describing the state of safety for the last few years. Between 2010 and 2012, there were 840,015 crashes reported in the state of Michigan (The Office of Highway Safety Planning 2013). Of these crashes, 121,224 occurred at signalized intersections. Twenty-seven percent of these crashes were classified as angle crashes, and 46% were classified as a rear-end crash, making these two the most commonly occurring crashes at signalized intersections. This is a trend that has also been observed around the globe (National Transportation Safety Board 2001; Yan, Radwan, & Abdel-Aty 2005; Wang, Ieda, & Mannering 2003). Of these two types of crashes at signalized intersections, 1.81% involved a fatal or incapacitating injury. Specifically in Oakland County, 20,414 crashes occurred at signalized intersections, or 19% of total crashes in the county within the same time period. Twenty-one percent of crashes at signalized intersections in the county were classified as angle crashes, and 53% were classified as rear-end crashes; 1.52% of crashes of one of these two types resulted in a fatal or incapacitating injury. These numbers show that Oakland County is below the state average in angle crashes, but above average in rear-end crashes. As it is also home to the FAST-TRAC SCATS system, these numbers may be telling of the safety impacts of SCATS systems.

Oakland County is one of the most populous counties in the state of Michigan. According to the 2013 census data, 1.2 million people make the county their home, or nearly 12% of the entire state population, with the majority of the population inhabiting the southeastern quarter of the county (2013 Census n.d.). The region consists of affluent, northern Detroit suburbs with little to offer in the way of mass transit options (American Public Transportation Association 2014). Consequently, heavy commuting passenger traffic leads to busy roads and an increased number of traffic signals to manage, thereby increasing the probabilities of the most common crashes at signals.

If adaptive traffic control systems are to become more prominent in the United States, as they are in other parts of the world, it must be made clear that not only are the performance benefits worth the investment of time and funding, but that they improve road networks in as many aspects as possible, including safety. It is therefore imperative to demonstrate that an adaptive traffic control system like FAST-TRAC improves not only performance but also safety.

## 3. Literature review

As traffic control systems have advanced with time, there have been a number of studies and developments improving the understanding of interactions occurring at intersections. Therefore, it is worthwhile to explore some of the existing literature on intersections and adaptive traffic technology.

Several safety-based studies that have been conducted on various ATCS installations were reviewed. A before–after study that included a comparison group focused on two roadways in Oakland County and showed a shift in injury severity towards less severe injuries. More specifically, a "shift in severity types A and B to type C" was found, which the researchers noted is significant (Dutta, Bodke, Dara, & Lynch 2010). Additionally, a survey conducted in 2013 with hopes of discovering safety benefits of adaptive systems concluded that there are safety benefits "for implementing [Adaptive Signal Control Technology]" regardless of the limited data, though no quantitative conclusions on safety effects could be drawn (Lodes & Benekohal 2013). Attempts have also been made to use microsimulation and the Surrogate Safety Assessment Model (SSAM) to determine safety benefits of adaptive systems. Two Utah state routes were used in a before–after study, with simulated results showing that a SCATS system generates 13.24% fewer rear-end crashes and 11.67% fewer total conflicts than traditional traffic control, while traditional traffic control generates fewer crossing and lane changing conflicts according to the model. Of note is that the research compared the model simulations to field crash data and found inconsistencies between the SSAM results and the field results, possibly due to the construction in the area during the data collection period (Stevanovic, Kergaye, & Haigwood 2011). VISSIM has also been used to simulate ATCS environments, resulting in the development of four algorithms that represent an adaptive traffic system and can be used for fine-tuning cycle lengths, splits, offsets, and left-turn phase sequences (Sabra, Gettman, Nallamothu, & Pecker 2013).

## 4. Methodology

This study makes use of cross-sectional analysis, a preferred method in traffic safety analysis when there are insufficient instances where the treatment was applied to conduct a before–after study (Washington, Karlaftis, & Mannering 2011). This analytical method is also a preferred method when a large data set is desired, as acquiring before–after data from a large number of sites can become laborious, time-intensive, and often impossible depending on the availability of historical data. In the case of this study, with the goal of network-level analysis, acquiring enough historical before–after data from the Road Commission for Oakland County (RCOC) and consulting firms involved in traffic signal upgrade projects from the last decade would be extremely difficult. While a cross-sectional analysis is therefore ideal for this type of study, it should be noted that it is only as strong as the variables included in the analysis, and therefore all possible variables may not have been included. Thus, only those variables determined to be the most relevant for this particular analysis have been included, although other factors could be considered in further study.

Selection of cross-sectional analysis as the analytical method enabled comparison between FAST-TRAC-controlled intersections in Oakland County to intersections in similar conditions found elsewhere in the state of Michigan. Specifically, intersections found in Lansing, Grand Rapids, and Kalamazoo that are in similar suburban environments equivalent to those suburban areas found in Oakland County were used for comparison purposes in a cross-sectional study approach and were considered a far enough distance away from Oakland County such that any driver expectation within a SCATS network would not be found to influence driving decisions in cities with pre-timed systems. Additionally, if a before–after approach were taken instead, the focus of the data would become significantly more focused on a few specific sites with available historical data from prior to a FAST-TRAC system upgrade. This method of narrowed analysis of FAST-TRAC was already conducted by Dutta, Bodke, Dara, and Lynch (2010) and Wolshon and Taylor (1999).

By using the provided list of FAST-TRAC-controlled intersections from RCOC, geometric data were collected using satellite imagery available on Google Maps. Data collected in this manner included the distance between signalized intersections, lane counts, land use, speed limits, and length in miles of the upstream road segment. Traffic counts in the form of average annual daily traffic (AADT) were also acquired