Traffic Impact Analysis (TIA) and Forecasting Future Traffic Needs: Lessons from Selected North Carolina Case Studies

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The focus of this paper is to conduct an evaluation of selected traffic impact analysis (TIA) case studies, review current practice, and recommend procedures that could be adapted to better forecast and plan future traffic needs. Lessons from the evaluations indicate that considering regional traffic growth rate, peak hour factor (PHF), heavy vehicle percentage, and other off-site developments would yield relatively better TIA forecasts. Incomplete development with vacant parcels was observed at several case sites, possibly due to the state of the economy. Therefore, conducting analysis assuming multiple "build out" years (say, three and five years based on the magnitude of the development) as complete build out years would help state and local transportation agencies plan and better allocate resources based on the need.

INTRODUCTION

Growth in population has led to increased travel demand that rapidly exceeded the designed capabilities of roads, leading to record levels of congestion (USDOT 2015). Long-term projections indicate that population, passenger-miles traveled, and traffic congestion are expected to continue rising (Cambridge Systematics, Inc. 2004). State and local transportation agencies are increasingly motivated to understand the impact of this growth and need to improve methods used in estimating future traffic conditions (CNT 2012).

Past studies primarily focused on the benefits of treatments pertaining to operational and safety performance of roadways near new developments (Levinson et al. 1996; Vargas and Reddy 1996; Parsonson et al. 2000; Bared and Kaisar 2002; Dissanayake and Lu 2003; Eisele and Frawley 2003; Eisele et al. 2004). However, the literature documents no formal evaluation to determine if the improvements and access scenario for new developments provided the traffic operational outcomes that had been forecasted in TIA studies before implementation. The difference in "what was forecasted to happen?" and "what is happening right now?" could be attributed to aspects such as incomplete or delayed development, using default peak hour factor (PHF) - defined as the ratio of peak hour traffic volume divided by four times the peak 15-minute traffic volume (Roess et al. 2004), using the default heavy vehicle percentage, and considering the traffic growth rate that may not be applicable to that area. Also, no research was done to analyze and evaluate the effectiveness of the methods used in TIA studies and suggest procedures to improve accuracy of the forecasts.

Most of the TIA guidelines provided by state and local transportation agencies incorporate adjacent traffic growth. However, inaccurate growth numbers would not yield precise results. Moreover, examining possible causes of traffic problems due to the off-site developments would help better identify appropriate solutions to serve traffic.

Traffic volume, delay, and level-of-service (LOS) are the measures of effectiveness (MOEs) typically considered in TIA studies. Considering other MOEs, such as the number of stops and 50th percentile queue length, would not only provide more insights on operational performance of intersections but also help in identifying suitable and appropriate solutions to improve traffic performance (e.g., use reduced signal cycle length or increase the number of left-turn lanes if queue length for left-turn traffic of an approach is very high). These MOEs typically are provided as outputs by Synchro® (Trafficware 2013) traffic simulation software, which is normally used by consultants in TIA forecasts.

Treatments such as traffic signals and additional lanes are used to reduce delays and crash risk at such locations by managing driveways, turning movements, and median openings between the two travel directions. These treatments not only help reduce the number of conflict points on roadways but also ensure a smooth flow of traffic. Though there is an improvement in traffic operation at intersections with such implemented treatments, it could affect the operational performance at adjacent intersections along the corridor. The literature documents no research on examining the effect of TIA recommendations at intersections adjacent to new developments.

The forecasted LOS outcomes from the TIA reports are often the sole basis for driveway (and even rezoning and site plan) approvals. Consequently, decision makers continue to authorize and conduct business on a preliminary study without detailed knowledge concerning the interim or ultimate performance of the development that accessed the road network. This often results in state and local transportation agencies re-engaging themselves in a defensive and re-active posture, investing limited funds to fix operational and safety problems following the opening of a major development (shopping centers, activity centers, power centers, schools, and other traffic generators) or a subsequent phase of a major development. Therefore, there is a need to research and evaluate the effectiveness of operational improvement treatments such as increasing driveway/intersection spacing, limiting median openings, adding new traffic signals, and adding turn lanes that are typically recommended in the TIA study. Lessons and the outcomes will be useful in addressing operational problems not only at new residential and commercial developments but also in retrofitting existing locations based on identified issues.

The objectives of this research paper are: 1) to conduct an evaluation of selected TIA case studies and 2) recommend a procedure (based on lessons learned) that could be adopted to conduct similar review assessments for flagged or random sites in the future so as to improve operational performance. Further, this research aims to find answers to questions such as:

1. What was expected to happen and what is happening now?
2. Which evaluation methods need to be adopted so as to yield better forecasts?
3. How do the TIA recommendations affect operational performance at intersections near and adjacent to the development?
4. What are the most/least effective treatments that would help improve traffic operations at TIA sites?

The answers to the above questions (findings from this research) will help state and local transportation agencies adopt accurate methods and implement treatments that benefit the transportation system users. The outcomes from this research are expected to contribute to significant business improvements and yield improved knowledge and practices with regard to what works, what does not work, and what departments of transportation (DOTs) or local transportation agencies can do to improve operational performance of roadways.

LITERATURE REVIEW

A TIA study assesses the impact of a proposed development on its street network depending on the characteristics of the development. The study provides recommendations to mitigate the negative impact of the development and also to enhance the performance of the road network surrounding the development. Edwards (Unknown Year) outlined the major benefits of a TIA study. They are listed as follows.

1. Forecast additional traffic and distribution/assignment associated with the new development based on acceptable local practices.
2. Determine the improvements/modifications/restrictions that are necessary to accommodate the new development.

3. Assist communities in land use decision making and in allocating scarce resources to areas that need improvement.
4. Identify potential problems with the proposed development that may influence a developer's decision to pursue it.
5. Reduce the negative impact of a development and ensure that the transportation network can accommodate the development.
6. Provide direction to community decision makers/developers of expected impacts and protect the community investment in the street system.

Not performing a TIA study may lead to failure in estimating the impact of development, which in turn can increase the number of conflicts, delay, and reduce the LOS on the roads. Similar to symptoms of poor access management (Stover and Koepke 2000), increase in crash rates, poor traffic flow, numerous brake light activations by drivers in the through lanes (indicators of delay and stops), increase in congestion, unaesthetic strip development, and neighborhoods disrupted by traffic and pressure to signalize more locations, widen an existing street, or build a bypass are some of the ill-effects observed in absence of an appropriate TIA study.

Analytical methods and operational tools are important to solve traffic engineering problems due to their efficiency in modeling and simulating real-world data and traffic performance. Some of the tools that are used to analyze various traffic facilities and scenarios are TRANSYT-7F™ (Wallace et al. 1984), CORSIM™ (FHWA 1996), Synchro® (Trafficware 2013), and VISSIM (PTV 2014). Bared and Kaisar (2002) used TRANSYT-7F™ and CORSIM™ to determine optimum signal setting and to represent geometric designs with variation in traffic flow at an intersection. Eisele and Frawley (2003) used VISSIM to quantify travel time, speed, and delay along the corridors. Synchro® was used to optimize the signal timings and results were incorporated into VISSIM for evaluation of the model in their study.

Muldoon and Bloomberg (2008) of the Oregon Department of Transportation (ODOT) suggested vital recommendations for the TIA process. The recommendations included more attention to the selection of apt land use code from the Institute of Transportation Engineers (ITE) Trip Generation Manual (ITE 2012), assumptions pertaining to pass-by trips (not produced or attracted to the development), seasonal variation of traffic, evaluation of alternate modes of transportation, traffic growth rates in the concerned area, future/horizon year analysis, and safety analysis. The study did not include any discussion on methods or tools for improved forecasts.

Treatments are typically recommended in TIA studies to accommodate access, improve traffic operations, and minimize the impact of the proposed new development. They include installing traffic signals, median treatments, adding lanes (left, right, and other), and unsignalized access points.

Traffic signals account for most of the delay experienced by motorists on the road network (Levinson et al. 1996). A traffic control signal should not be installed unless an engineering study indicates that installing a traffic control signal will improve the overall safety and/or operation of the intersection (FHWA 2003). Closely spaced signals along a corridor result in increased travel delay, frequent stops, and increased fuel consumption with excessive vehicular emissions.

Median treatments, between both travel directions, are considered as one of the most effective practices, as they play a vital role in controlling operational and safety aspects on roadways. Pedestrian and vehicular safety can be improved through the use of medians. They are generally classified into three types (TRB 2003): undivided median, two-way left-turn lanes (TWLTL), and raised median.

Widening roads is generally expected to improve the operational performance, and hence, often a very common recommendation in the TIA studies. Dunay et al. (2000) observed counter-intuitive results that adding lanes makes traffic worse. Their article documented the suspected paradox that the highways built around New York City in 1939 were generating greater traffic problems than those that existed prior to 1939. Moreover, they mentioned that adding lanes or even double-decking the roadways would have no more than a cosmetic effect on traffic problems.

Unsignalized access points increase the number of conflicts on driveways. These conflict points slow down vehicles and even increase crash rates, especially where left turns must cross two or more lanes of opposing traffic. As stated in AASHTO (2001), driveways are effectively the same as intersections and should be designed consistent with their intended use. The numbers of crashes are disproportionately higher at driveways than at intersections; therefore, their design and location merit special consideration.

Overall, the literature documents articles and reports on TIA recommended treatments and operational/safety effects due to the implementation of these treatments. No research or documented evidence was found on the evaluation of both the effectiveness of TIA reports and operational performance of adopted recommended treatments. Addressing questions such as “what was expected to happen and what is happening now?” and comparing the two will serve as valuable inputs when conducting future TIA studies. In addition, developing and using accurate and proven methods to forecast the effects will help make better decisions and contribute to improved transportation system performance.

RESEARCH METHOD

The research method adopted involves the following four steps:

1. Select TIA case studies
2. Identify measures of effectiveness (MOEs)
3. Collect data
4. Conduct operational evaluation using selected methods
5. Analyze effectiveness of treatments

Select TIA Case Studies

The focus of this step is to identify TIA case studies for evaluation such that they are geographically distributed throughout the state of North Carolina. They also should represent different levels of urbanization (urban and suburban areas) and land use within their vicinity.

Identify Measures of Effectiveness (MOEs)

MOEs pertaining to operational aspects of a roadway (such as stops, queue length, delay, and LOS) are selected and used to conduct analyses of data and evaluate the effectiveness of forecasted methods. The LOS categories are defined as follows (TRB 2010).

Intersection Delay (sec/veh)	LOS
≤10	A
> 10-20	B
> 20-35	C
> 35-55	D
> 55-80	E
> 80	F

Collect Data

Published TIA reports (based on studies conducted prior to the construction of the development) comprising operational data (traffic volume, stops, queue length, delay, and any other appropriate data) “before” construction of the development and forecasted “after” construction of the development were collected for each selected case study. These reports also have details of future traffic conditions with and without the development, and whether the existing system will be able to accommodate the additional traffic generated by the development at the site.

In addition, traffic volume, the number of stops, queue length, and delay along with geometric conditions were collected to represent conditions during the "build" condition (year) at the selected intersections (or locations) near each TIA site. Due to resource limitation, the number of stops, queue length, and delay were only collected for left-turning traffic and through traffic, while traffic volume and geometric conditions were captured for the entire intersection. The exclusion of queue length and delay for right-turning traffic was not expected to have notable effect on the considered MOEs as right-turning vehicles (generally low in number) are allowed to turn right on red at more than 99% of signalized intersections in North Carolina.

The day of the week and durations for data collection were determined based on the duration of data collection used in collected TIA reports. Accordingly, data were collected for one day during the morning peak hours (7 AM - 9 AM) and evening peak hours (4 PM - 6 PM) in this research. Trained observers were used to collect the data in the field. Both manual and video data collection methods were adopted.

Conduct Operational Evaluation Using Selected Methods

The evaluation of operational performance and forecasting methods was conducted using three different methods. Traffic volume, geometric conditions, and MOEs for "no build" condition and forecasted for "build" condition are from TIA reports, while MOEs computed using traffic volume and geometric condition data collected during the study year (2009) for the "build" condition are from this research effort. The PHF, heavy vehicle percentage, traffic growth rate, and current signal timing information specific to the intersections at the site were used to compute MOEs in this research. Default driver and vehicle related characteristics were used for analysis.

Method 1: Study the Operational Performance Before and After the Development at the Site. In this method, the traffic volume and selected MOEs in the TIA reports for the "no build" condition are compared with the same MOEs computed using traffic volume and geometric conditions data collected during 2009 for the "build" condition. These MOEs are computed using Synchro® traffic simulation software. This method helps in studying the effect of the new development with recommended treatments at intersections near and adjacent to the development.

Method 2: Study the Effectiveness of Methods to Forecast the Operational Effects Due to the Development. This method helps in studying the effect of methods used to forecast traffic needs due to a new development. MOEs for the "build" condition forecasted in the TIA reports are compared with the same MOEs for the "build" condition computed using traffic volume and geometric conditions data collected during 2009. These MOEs are computed using Synchro® traffic simulation software.

Method 3: Study the Effectiveness of the Research /Traffic Simulation Software. The selected MOEs, such as the number of stops and delay collected in the field during 2009 for the "build" condition, are compared to the same MOEs computed using Synchro® traffic simulation software (considering traffic volume and geometric conditions data collected during 2009) for the "build" condition. This method identifies the effectiveness of the adopted TIA procedure in replicating the real-world data and operational performance. It also provides insights to obtain better estimates of traffic conditions in the future.

Analyze Effectiveness of Treatments

Analysis was carried out to compare intersection delay under “no build” conditions during 2009 and “build” conditions during 2009. This helps to examine if there was an increase or decrease in intersection delay after the development with the deployed treatments (“build” condition during 2009) when compared with the projected study year “no build” condition.

ANALYSIS & RESULTS

Six TIA case studies in the state of North Carolina were selected for data collection, analysis and evaluation. Table 1 shows information pertaining to location, type, build-out year, percent of development completed as of spring 2010, and level of urbanization of all six TIA sites selected for this research. The first four sites are in the Charlotte region, while the last two sites are in the Raleigh area.

For illustration purpose, WT Harris Boulevard Primax Site is discussed in detail in this paper. MOEs are summarized at intersection level (not by approach and turning movement). Readers are referred to the study conducted for the North Carolina Department of Transportation (NCDOT) for analysis of sites pertaining to all case studies (Pulugurtha and Mora 2010).

Table 1: Selected TIA Case Study Sites and Their Characteristics

Site	Type of Development	TIA Study/Start Build Year	Anticipated Full Build Out Year	% Completed at the time of this Research	Level of Urbanization
WT Harris Boulevard Primax	Commercial	2004	2009	75	Urban
Mountain Island Square	Mixed Land Use	2004	2009	60	Sub-urban
Cato Property	Residential	2004	2010	95	Sub-urban
University Pointe	Commercial	2005	2010	70	Urban
Midway Plantation	Commercial	2005	2007	95	Urban
Retail Development at Youngsville	Commercial	2005	2008	75	Sub-urban

Primax Properties, LLC, proposed a commercial development located on an approximately 549,000 square feet vacant area in the southeast quadrant of E. WT Harris Boulevard (NC 24) / Rocky River Road (SR 2828) intersection in Charlotte. The property was planned to be completed in 2009 (“build out” year). Following are the intersections that are under the area of influence of the site (as indicated in the WT Harris Boulevard Primax site TIA report). The type of intersection control, whether existing or proposed and near or adjacent to the development, are shown in parentheses.

1. E. WT Harris Boulevard (NC 24) / Rocky River Road (SR 2828) (existing; signalized; near)
2. E. WT Harris Boulevard (NC 24) / Grier Road (SR 2976) (existing; signalized; adjacent)
3. Rocky River Road (SR 2828) / Grier Road (SR 2976) (existing; signalized; adjacent)
4. Rocky River Road (SR 2828) / Proposed Access A (unsignalized; proposed; near)
5. E. WT Harris Boulevard (NC 24) / Proposed Access B (unsignalized; proposed directional crossover; near)

The operational performance at intersections 1, 2, and 3 was evaluated using the three different methods. Traffic data were collected from TIA reports and in the field (using manual and video data collection methods) to compute MOEs such as the number of stops, delay, and LOS at these intersections using Synchro® 6.0 traffic simulation software. Table 2 summarizes traffic data by approach and turning movement from TIA reports (both before development and forecasted) and observed in the field (year 2009).

Table 2: Traffic Volume Before, Forecasted, and Observed After Development (WT Harris Boulevard Primax Site, Charlotte, North Carolina)

Approach	Turning Movement	Morning Peak Hour			Evening Peak Hour		
		Before (2004)	Forecasted (2009)	Observed (2009)	Before (2004)	Forecasted (2009)	Observed (2009)
E. WT Harris Blvd / Rocky River Rd*							
Eastbound	L	14	51	53	25	101	77
	T	53	94	82	238	348	72
	R	71	82	11	57	66	22
Westbound	L	102	153	115	23	122	77
	T	143	192	31	44	76	31
	R	619	938	718	105	265	318
Northbound	L	27	91	36	36	102	43
	T	1,710	2,014	1,607	1,253	1,524	1,378
	R	22	28	10	30	44	84
Southbound	L	59	209	102	435	771	726
	T	1,064	1,338	1,047	1,631	1,974	1,623
	R	9	24	41	22	37	52
E. WT Harris Blvd / Grier Rd							
Eastbound	L	34	70	42	43	71	82
	T	65	151	113	339	513	317
	R	196	227	148	289	335	306
Westbound	L	379	638	344	105	248	286
	T	382	554	327	95	173	132
	R	15	17	69	28	32	52
Northbound	L	236	277	213	208	245	205
	T	1,769	2,120	1,651	1,262	1,525	1,411
	R	130	247	220	441	688	486
Southbound	L	25	91	75	25	87	119
	T	1,130	1,339	1,010	1,130	1,807	1,574
	R	39	64	39	39	79	56
Rocky River Rd / Grier Rd							
Eastbound	L	95	276	133	653	1,132	771
	R	1	1	19	15	17	50
Northbound	L	6	7	13	9	10	7
	T	175	369	194	731	1,140	674
Southbound	T	753	1,193	703	175	378	352
	R	821	1,306	850	152	415	364

L, T and R above indicate left-turn, through and right-turn movements, respectively.

* indicates intersection is closest to the development/site

Traffic volume (shown in Table 2) increased considerably (more than the general 3% annual growth of traffic on the roads) at all the three study intersections after the development at the TIA site. Moreover, the forecasted traffic volumes involve very large errors relative to the observed traffic volumes.

Method 1: Study the Operational Performance Before and After the Development

Table 3 shows the total number of stops, intersection delay, and intersection LOS for "no build" condition from TIA reports and computed using traffic volume and geometric conditions data collected during 2009 for the "build" condition.

The number of stops and intersection delay increased from 2004 ("no build" condition) to 2009 ("build" condition) at all the three intersections near the site during the evening peak hours, but only at one intersection near the site during the morning peak hours. The cause can be attributed to site traffic/off-site development growth, changes in signal timing patterns, and, use of PHFs and heavy vehicle percentages from field observations for the "build" condition. The increase in intersection delay could also be due to construction of two new access points near the new development.

Table 3: Delay and LOS Before and After Development (WT Harris Boulevard Primax Site, Charlotte, North Carolina)

Intersection	Morning Peak Hour			Evening Peak Hour		
	# Stops	Delay (sec/veh)	LOS	# Stops	Delay (sec/veh)	LOS
TIA Reports - 2004 (No Build Condition)						
WT Harris Blvd / Rocky River Rd*	1,635	26.6	C	2,593	37.7	D
WT Harris Blvd / Grier Rd	3,696	50.2	D	2,333	32.2	C
Rocky River Rd / Grier Rd	635	12.6	B	1,259	35.6	D
Computed from Field Counts - 2009 (Build Condition)						
WT Harris Blvd / Rocky River Rd*	1,892	34.2	C	3,061	38.9	D
WT Harris Blvd / Grier Rd	3,027	49.9	D	3,888	72.0	E
Rocky River Rd / Grier Rd	554	7.0	A	1,516	40.4	D

* indicates intersection is closest to the development/site

Method 2: Study the Effectiveness of Methods to Forecast the Operational Effects of the Development

The MOEs for the "build" condition forecasted in the TIA reports were compared with the MOEs for the "build" condition using traffic volume and geometric conditions data collected during 2009 and computed using Synchro® traffic simulation software (Table 4). The total number of stops, intersection delay, and intersection LOS are shown in the table. The results were used to evaluate "what was expected to happen and what is happening now?"

The computed delays for the "build" condition from TIA reports during the morning peak hour are slightly lower than the computed delays from field counts for two of the three study intersections. The forecasted delay at the intersection next to the development, E. WT Harris Boulevard/Rocky River Road intersection, during the evening peak hour was higher than the current delay, while the delay at E. WT Harris Boulevard/Grier Road was lower than observed delay. The delay at the Rocky River Road/Grier Road intersection was higher during the morning peak hour and lower during the evening peak hour than the observed delay.

Table 4: Delays and LOS - Forecasted vs. Computed (WT Harris Boulevard Primax Site, Charlotte, North Carolina)

Intersection	Morning Peak Hour			Evening Peak Hour		
	# Stops	Delay (sec/veh)	LOS	# Stops	Delay (sec/veh)	LOS
Forecasted from TIA Reports - 2009 (Build Condition)						
WT Harris Blvd / Rocky River Rd*	3,310	32.3	C	4,571	63.7	E
WT Harris Blvd / Grier Rd	4,683	42.8	D	4,567	50.0	D
Rocky River Rd / Grier Rd	1,296	24.8	C	2,053	26.0	C
Computed from Field Counts - 2009 (Build Condition)						
WT Harris Blvd / Rocky River Rd*	1,890	34.2	C	3,071	38.9	D
WT Harris Blvd / Grier Rd	3,027	49.9	D	3,888	72.0	E
Rocky River Rd / Grier Rd	554	7.0	A	1,516	40.4	D

* indicates intersection is closest to the development/site

The total number of stops from TIA reports (forecasted) are higher than those computed from field counts, at all three study intersections, during both morning and evening peak hours.

The difference in forecasted and computed number of stops, delay, and LOS for the “build” condition could be due to 1) the use of PHFs and heavy vehicle percentages from field observations, and, 2) existing signal timing patterns that are different than those used in the TIA. In addition, the planned completion year of the proposed development is 2009. However, field visits indicate that only 75% of the proposed development was complete by the spring of 2010. Overall, differences in what was expected to happen are observed based on analysis.

Method 3: Study the Effectiveness of Research/Traffic Simulation Software

The number of stops and delay observed directly from the field were compared to those computed from the Synchro® analysis to examine the effectiveness of the research or traffic simulation software in forecasting traffic condition. As stated previously, these data were only collected for left-turning and through traffic. Since the research has incorporated factors that are omitted in the TIA study, results from this method suggest consideration of additional factors to better forecast future needs. The observed average delay and computed average delay are shown in Table 5.

Table 5: Delays and LOS - Observed vs. Computed (WT Harris Boulevard Primax Site, North Carolina)

Intersection	Morning Peak Hour			Evening Peak Hour		
	# Stops	Delay (sec/veh)	LOS	# Stops	Delay (sec/veh)	LOS
Observed in the Field - 2009 (Build Condition)						
WT Harris Blvd / Rocky River Rd*	806	35.0	C	1,344	39.0	D
WT Harris Blvd / Grier Rd	1,588	45.0	D	2,574	44.0	D
Rocky River Rd / Grier Rd	301	7.0	A	1,971	33.0	C
Computed from Field Counts - 2009 (Build Condition)						
WT Harris Blvd / Rocky River Rd*	1,561	34.2	C	2,882	38.9	D
WT Harris Blvd / Grier Rd	2,872	49.9	D	3,426	72.0	E
Rocky River Rd / Grier Rd	301	7.0	A	1,486	40.4	D

* indicates intersection is closest to the development/site.

The observed total number of stops is lower than the computed number of stops for two of the three study intersections. The observed delay at E. WT Harris Boulevard/Rocky River Road intersection are close to the computed delay during the morning and evening peak hours. At E. WT Harris Boulevard/Grier Road intersection and Rocky River/Grier Road intersection, the observed delays are close to the computed delays during the morning peak hour, while the observed delays are lower than the computed delays for two intersections during the evening peak hour. The estimates had an effect on LOS at these two intersections during evening peak hours.

The difference in observed and computed number of stops for two of the study intersections could be attributed to exclusion of right-turning traffic in the field for capturing these MOEs. The relatively high difference between observed and computed delay during evening peak hours for WT Harris Boulevard/Grier Road intersection could be due to unusually high right-turning traffic for one of the approaches or inability of the traffic simulation software to forecast accurately for the observed traffic volume conditions. The difference in delays was observed to be marginal for the other two intersections or durations.

Summary of Results for All TIA Case Study Sites

As shown in Table 1, the "build-out" year varied from 2007 to 2010 for the selected TIA sites. However, the percent of development completed varied from 60% to 95% as of spring 2010.

Table 6 compares the PHF, heavy vehicle percentage, and traffic growth rate for all the sites. These are additional factors considered in this research. Both default values assumed and used by consultants who prepared TIA reports and actual observations from the field are shown in the case of PHFs and heavy vehicle percentages. The computed PHFs based on observed traffic data at the selected intersections of TIA sites varied from 0.87 to 0.97, while consultants used a default value of 0.90. Likewise, heavy vehicle percentages varied from 0% to 5% at the selected intersections of TIA sites, while consultants used a default value of 2%.

In general, traffic volumes forecasted at the selected TIA sites in the TIA reports are observed to be higher than those observed in the field (Table 2). The percent difference is high though the forecasted and observed right-turn traffic volumes differed by a low value. The numbers of stops from the TIA also followed a similar pattern as traffic volume. The difference in results obtained could be attributed to assumed default growth rate (3%), which did not reflect the real-world scenario. In reality, the growth rates varied from -9% to +25% at the selected intersections of TIA sites.

Table 6: Observed PHF, Heavy Vehicle Percentage, and Growth Rate

Site	Intersection	Time period	PHF	Heavy Vehicle (%)	Traffic Growth Rate
WT Harris Boulevard Primax	E. WT Harris Blvd / Rocky River Rd	AM	0.89	2.0	0.0
		PM	0.92	1.2	3.0
	E. WT Harris Blvd / Grier Rd	AM	0.95	3.8	-1.0
		PM	0.96	2.0	5.0
	Rocky River Rd / Grier Rd	AM	0.95	2.0	1.0
		PM	0.92	2.0	5.0
Mountain Island Square	Brookshire Blvd / Mt. Holly Huntersville Rd	AM	0.93	1.0	0.0
		PM	0.93	0.6	14.0
	Mt. Holly Huntersville Rd / Callabridge Ct	AM	0.96	2.0	-6.0
		PM	0.94	0.0	5.0
Cato Property	Tom Short Rd / Ballantyne Commons Pkwy	AM	0.86	3.0	10.0
		PM	0.94	0.0	5.0
	Tom Short Rd / Ardrey Kell Rd	AM	0.97	4.0	17.0
		PM	0.95	1.0	15.0
	Ardrey Kell Rd / Providence Rd	AM	0.96	2.0	11.0
		PM	0.92	1.0	2.0
	Providence Rd / Allison Woods Dr	AM	0.93	1.0	3.0
		PM	0.91	0.5	3.0
University Pointe	North Tryon St (US 29) / McCullough Dr	PM	0.96	1.0	2.0
	North Tryon St (US 29) / The Commons at Chancellor Park Dr	PM	0.96	0.6	N/A
Midway Plantation	Knightdale Blvd (US 64) / Southbound Off Ramp	AM	0.95	5.0	-9.0
		PM	0.94	2.0	-3.0
	Knightdale Blvd (US 64) / Northbound On Ramp	AM	0.89	5.0	-3.0
		PM	0.89	1.0	12.0
	Knightdale Blvd (US 64) / Site Drive #1 (Hinton Oaks Blvd)	AM	0.90	4.0	1.0
		PM	0.94	1.0	12.0
	Knightdale Blvd (US 64) / Site Drive #3 (Wide Waters Pkwy)	AM	0.94	4.0	0.0
		PM	0.87	2.0	25.0
Retail Development at Youngsville	US 1 / NC 96	AM	0.92	2.0	-2.0
		PM	0.92	2.0	0.0
	US 1 / Mosswood Blvd	AM	0.94	2.0	-3.0
		PM	0.91	2.0	-2.0

Note: 0.9, 2% and 3% were assumed as PHF, heavy vehicle % and growth rate in selected TIA studies.

Effectiveness of Treatments

Analysis was conducted to compare delay at intersections near each site before and after the development with the deployed treatments, and to study if there was an increase or decrease in the intersection delay due to deployed treatments. The treatments installed at the six TIA sites included additional right-turn or left-turn lane, additional approach/leg (convert three-legged intersection to four-legged intersection), installation of traffic signal, access points, and un-installation of directional (provision of left turns in one direction only) crossovers. Table 7 summarizes treatments implemented after development, at the time of this research, at each TIA case study site.

Table 7: Summary of Treatments by TIA Case Site

Treatment	WT Harris Primax	Mt. Island Square	Cato Property	University Pointe	Midway Plantation	Retail Development at Youngsville
Additional right turn lane	X			X		
Additional left turn lane	X	X	X	X	X	
Traffic signal Installation		X		X		
Reducing cycle length			X			
Increasing cycle length			X			
Additional approach/leg	X		X	X		X
Access points	X		X		X	
Uninstallation of directional crossover*				X		

* Provision for left-turns in one direction only.

The "no build" condition data were projected to the year 2009 so as to reflect the growth in traffic and for easy comparison. The projections were based on a pre-approved 3% traffic growth rate recommended for use in TIA by NCDOT. The delay based on the projected data was then compared to operational performance based on 2009 field data (Table 8). An increase in delay, in particular, during evening peak hours was observed at most of the study intersections. These trends seem to be similar and consistent irrespective of the type of treatment and development. Also, an increase in delay and decrease in operational performance was observed at adjacent intersections in addition to the intersection near the site. As expected, a decrease in the effect was observed with an increase in distance of an intersection from the development.

Table 8: Change in Intersection Delay for 2009 "No Build" and "Build" Conditions at Intersection Near and Adjacent to TIA Case Site

Site	Intersection	Delay	
		AM	PM
WT Harris Boulevard Primax	E. WT Harris Blvd / Rocky River Rd*	I	I
	E. WT Harris Blvd / Grier Rd	D	I
	Rocky River Rd / Grier Rd	D	I
Mountain Island Square	Brookshire Blvd / Mt. Holly Huntersville Rd	I	I
	Mt. Holly Huntersville Rd / Callabridge Ct*	I	I
Cato Property	Tom Short Rd / Ballantyne Commons Pkwy*	I	I
	Tom Short Rd / Ardrey Kell Rd	I	I
	Ardrey Kell Rd / Providence Rd	I	I
	Providence Rd / Allison Woods Dr		
University Pointe	North Tryon St (US 29) / McCullough Dr		D
	North Tryon St (US 29) / The Commons at Chancellor Park Dr*		I
Midway Plantation	Knightdale Blvd (US 64) / Southbound Off Ramp	D	D
	Knightdale Blvd (US 64) / Northbound On Ramp	I	I
	Knightdale Blvd (US 64) / Site Drive #1 (Hinton Oaks Blvd)	I	I
	Knightdale Blvd (US 64) / Site Drive #3 (Wide Waters Pkwy)*	I	I
Retail Development at Youngsville	US 1 / NC 96*	I	I
	US 1 / Mosswood Blvd	D	I

Note: "I" indicates an increase and "D" indicates decrease in intersection delay.
* indicates intersection is closest to the development/site.

CONCLUSIONS

Traffic volume and MOEs such as the number of stops and delay at intersections near the development generally increased after the development was built. This can be attributed to general growth of traffic and traffic generated by the new development. It was also observed that other off-site developments aggravated traffic problems at some intersections. Traffic generated by these off-site developments was either under-estimated or not considered in the TIA. The MOEs were generally over-estimated when conducting TIA. The computed ratios tend to be very high for lower values (say, low right-turn traffic volume along an approach) than when compared to those with higher values.

Field observations at the study intersections yielded very different PHFs and heavy vehicle percentages than default values. While using default PHF and heavy vehicle percentage values (0.9% and 2%, respectively) would yield conservative forecasts if PHF is greater than 0.9 and heavy vehicle percentage is less than 2%, it may not be appropriate or suitable when PHF is lower than 0.9 or heavy vehicle percentage is greater than 2%. Therefore, where appropriate, lower PHFs or higher heavy vehicle percentages than default values are recommended for use.

The cycle lengths and signal phasing/timing parameters used in TIA are different from what was observed in the field under current conditions. This had an effect on "what was forecasted to happen?" and "what is happening right now?" It is therefore recommended that suggested TIA guidelines be considered while designing signal timing and phasing for TIA (in addition to analysis based on existing signal phasing and timing data). This would also assist in easy comparison and effective evaluation of treatments after the deployment.

A pre-approved default growth rate of 3% was used in projecting future traffic in most of the TIA reviewed as a part of this research. The growth rate may vary based on changes to land use characteristics, off-site developments, and the type of facility. Therefore, considering traffic growth rate within the vicinity of the site will yield better estimates.

In most of the TIA reports, traffic conditions were forecasted using three years as the time frame for completion of construction. Several proposed developments and improvements were not complete (vacant parcels and incomplete implementation of transportation projects possibly due to the state of the economy) at the time of this research (though the complete build out year was 2009 for most case sites were considered). The percent of development completed at the selected study sites varied from 60% to 95%. It would help if consultants carry out analysis with multiple build-out years (say, three and five years based on the magnitude of the development) and present analysis for the same. For instance, a development was scheduled for full build out in three years. If the construction was delayed due to unforeseen conditions (such as a fall in the economy), it would allow the decision makers to plan and implement treatments based on the status of construction ("build" condition).

As stated before, incomplete development was observed during 2009 at several case sites. However, the observed MOEs are higher in value than the forecasted MOEs even with partial development at most of the sites considered in this research. Collecting and analyzing data under "ground-zero" conditions prior to start of construction of the development in addition to collection and analysis of data at regular intervals (say, every year) throughout the construction of the development would help better understand the operational effects of new developments. On the other hand, since uncertainty may prevail during the project construction, it would better help the decision makers if a range of MOE forecasts is available from the TIA study depicting the best/worst case scenarios. This would also help identify, plan, and deploy treatments at suitable times over the project duration in the future.

TIA studies do not generally include safety evaluation of the site. Including safety evaluation would help better understand the effect of the development and treatments on crashes at intersections near the site. Further, data collected for one day are normally used in TIA. Collecting and using data for multiple days would eliminate the variability that can lead to any biased results. Using average day data observed from multiple days or average results from analysis done for multiple days would yield more realistic outputs.

Overall, it can be concluded that ignoring the PHFs, heavy vehicle percentages, local growth rates, and off-site developments would not yield the best results. Some results obtained (example, decrease in traffic volume) in this research may seem counter-intuitive in nature. However, lessons learned from this research serve as valuable inputs to DOTs in making decisions or adopting policies that would lead to use of better methods for forecasting the impacts of new developments.

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Disclaimer

The contents of this paper reflect the views of the authors and not necessarily the views of the University. The authors are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of either the North Carolina Department of Transportation or the Federal Highway Administration at the time of publication. This report does not constitute a standard, specification, or regulation.

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