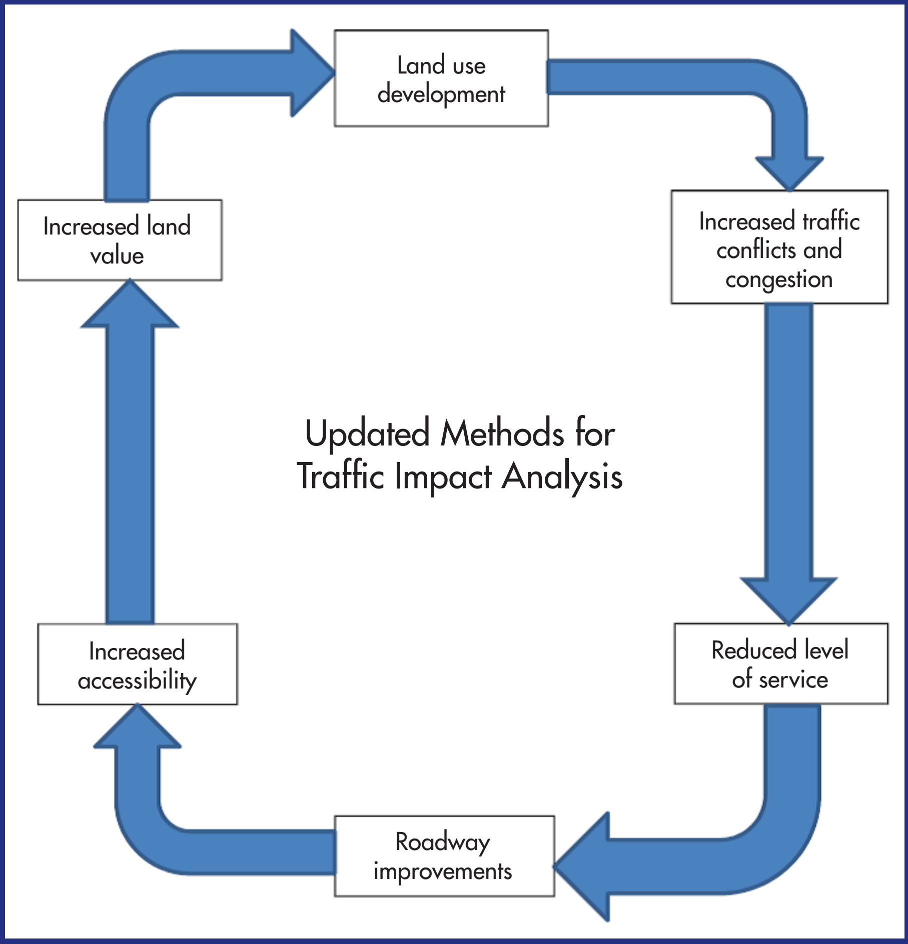
JOINT TRANSPORTATION RESEARCH PROGRAM

INDIANA DEPARTMENT OF TRANSPORTATION
AND PURDUE UNIVERSITY

Updated Methods for Traffic Impact Analysis, Including Evaluation of Innovative Intersection Designs

Volume I—Technical Report



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Most importantly, this report is dedicated to Stephen C. Smith of INDOT's Division of Planning & Asset Management, Technical Planning Section, who passed away on 30 May 2013, as this report was being completed. Steve was the motivator for the 1991 Traffic Impact Analysis Project HPR-2039, which put Indiana among the leaders in TIA. Among his many responsibilities and accomplishments, he maintained a keen interest in TIA and led the development of INDOT's Access Management Study, Documents, and Draft Policies.

JOINT TRANSPORTATION RESEARCH PROGRAM

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16. Abstract

In 1992, an Applicant's Guide and a Reviewer's Guide to Traffic Impact Analyses to standardize the methodologies for conducting traffic impact analyses (TIAs) in Indiana were developed for the Indiana Department of Transportation (INDOT). The methodologies were meant to help streamline the process of preparing and reviewing TIAs. The methodology is applicable for other transportation and government entities as well. Because 20 years have passed since the publication of the guides, INDOT wished to evaluate how effective the guides have been, determine what in the guides has worked well, revise parts of the guides that have not worked well, and add improvements and changes that have occurred since the guides' publication. Brief explanations of innovative intersection alternatives such as roundabouts, median U-turns (MUT), restricted-crossing U-turns (RCUT), displaced left-turns (DLT), and quadrant roadways (QR) are provided to increase awareness of these possible designs. Some of the innovative designs were compared against a two-way stop-controlled intersection and a conventional signalized intersection for varying volumes on minor street approaches. The median U-turn design seemed to perform better at higher, more balanced flows whereas the roundabout performed better for unbalanced flows. At times, a development affects roads in more than one jurisdiction. Ideas are presented that may facilitate the inclusion of all affected parties early in the development process to improve communication, address all possible effects of the development and better satisfy all affected parties.

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EXECUTIVE SUMMARY

UPDATED METHODS FOR TRAFFIC IMPACT ANALYSIS, INCLUDING EVALUATION OF INNOVATIVE INTERSECTION DESIGNS

Introduction

In 1992, an applicant's guide to traffic impact analysis and a reviewer's guide to traffic impact analysis were developed for the Indiana Department of Transportation (INDOT). The methodologies they contained were meant to (a) standardize the methodologies for conducting traffic impact analyses (TIAs) in Indiana and (b) to help streamline the process of preparing and reviewing TIAs. Because 20 years have passed since the publication of the guides, there is a need to

- evaluate how effective the guides have been,
- determine what in the guides has worked well,
- revise parts of the guides that have not worked well, and
- incorporate improvements and changes in TIA that have occurred since the 1992 guides' publication.

Findings

- The researchers used surveys, meetings, and informal conversations to collect comments about the applicant's guide from INDOT personnel, engineering consultants, and local public officials. The comments were mostly positive, but the researchers were able to assemble a list of about 15 items that should be considered for inclusion in the updated guide. See Chapter 3.
- Updated procedures for pass-by trips and for internal trips at mixed use sites were reviewed and demonstrated.
- Legal issues regarding TIA report preparer credentials, rights of access to property, and traffic impact fees were clarified.
- The updated guides were made compatible with the current editions of the ITE Recommended Practice, INDOT's Access Management Guide, INDOT's Design Manual, and other documents of value to TIA.
- The validity of using traffic microsimulation software to evaluate non-traditional intersection technologies was confirmed.
- Suggestions were made for enhancing the cooperation between jurisdictions when a development will have traffic impacts in more than one jurisdiction.

The project findings are documented in three volumes: (1) a technical report, (2) an applicant's guide to traffic impact analysis, and (3) a reviewer's guide to traffic impact analysis.

Implementation

Traffic impact analysis is a field that has matured, with many of its practitioners aware of standard practice and new methods. The applicant's guide contains flow diagrams and checklists that will continue to govern the phases of a TIA: preliminary steps, initial (scoping) meeting, TIA report format, and review process.

This project was conducted under the supervision of a study advisory committee that included INDOT personnel, local public officials, and a consultant. Other consultants were also given the opportunity to comment on the draft applicant's guide. For this reason, the principal stakeholders in a traffic impact analysis are comfortable with the results of this project. Implementation should be immediate and effective. A workshop for potential users of the guides has been suggested.

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1. INTRODUCTION

1.1 Background

In 1992, the Indiana Department of Transportation (INDOT) published a 3-volume report based on Research Project HPR-2039.

- Volume 1. Manual of Traffic Impact Studies: Guidelines for Traffic Analysis of Developments along State Highways.
- Volume 2. Applicant's Guide to Traffic Impact Studies
- Volume 3. Reviewer's Guide to Traffic Impact Studies

The 1992 manual and guides sought to accomplish two main goals. The first goal was to simplify the process for determining when and to what extent a traffic impact analysis is needed. This was done by creating an easy-to-follow flow chart (Figure 1.1) and specified threshold values (Table 1.1). (An updated version of Figure 1.1 will be placed in the updated Applicant's Guide.) Two steps in Figure 1.1 should be described and clarified.

- Are warrants for TIS met? This involves a preliminary estimate of the traffic generated by the site, which will be added to the existing traffic to determine if a full traffic operations analysis is warranted. If such an analysis is warranted, the "Yes" path will be followed, leading to Conduct TIS.
- If the Staff Review of the TIS indicates that Changes [are] needed, the need for Conduct traffic operations analysis can be confirmed and a study of capacity and level of service for proposed traffic control and geometric features will be conducted.

By using the threshold values and flow chart, the extent of the analysis needed could be determined very early in the process. INDOT was made aware of the proposed development and the developer received early guidance as to what was expected by INDOT regarding driveway location(s) and extent of the TIS. The second goal was to clarify expectations for both applicants and reviewers (*1*). This allowed applicants to understand what would be expected by the reviewers, and the reviewers had clarity as to what to be looking for when reviewing traffic impact analyses. This helped speed up the review process by informing applicants of what is expected in a traffic impact analysis report and giving reviewers a list of important items to check. The manual and guides have been used across the state since their publication.

1.2 Traffic Impact Analysis

A traffic impact analysis (TIA) is conducted to estimate the impact of the traffic generated by a proposed development will have on the surrounding transportation network. The number of trips generated by the development are estimated and distributed onto the transportation network surrounding the site. The surrounding transportation network is then analyzed to determine if acceptable levels-of-service are being provided, or if the site-generated traffic is significant

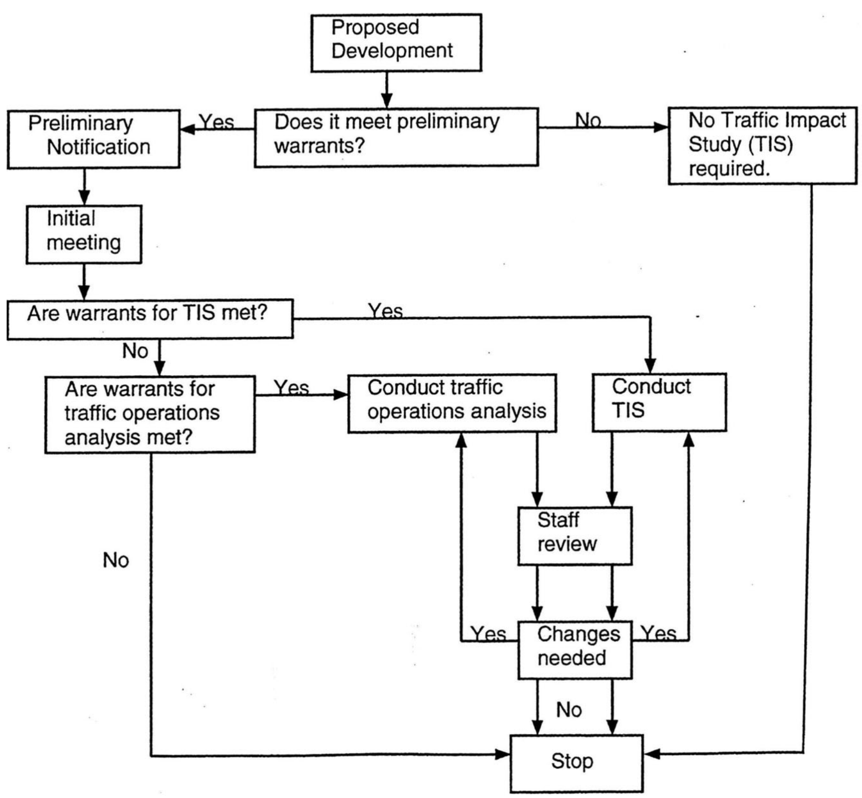


Figure 1.1 Flowchart showing the traffic impact study procedure (*1,2*).

TABLE 1.1
Preliminary warrants for traffic impact analysis (*1,2*)

Land use type	ITE code	Threshold values
Residential	210, 220, 222, 230, 270	150 dwelling units
Retail	814, 815, 820	15,000 square feet
Office	710, 714, 715, 750, 770	35,000 square feet or 3 acres
Industrial	110, 120, 130, 140	70,000 square feet or 9 acres
Educational	520, 530, 550	30,000 square feet or 250 students
Lodging	310, 312, 320	120 occupied rooms
Medical	610	46,000 square feet

enough to warrant improvements to the network. If improvements are needed, then recommended improvements to the transportation network are provided with the results of the analysis that are submitted to the governing jurisdiction for approval.

Traffic impact analyses have many components. (See Figure 1.2.) The analysis requires inputs such as current transportation network geometry, current and predicted traffic counts and intersection control and parameters (i.e., signal timing plans). New traffic from

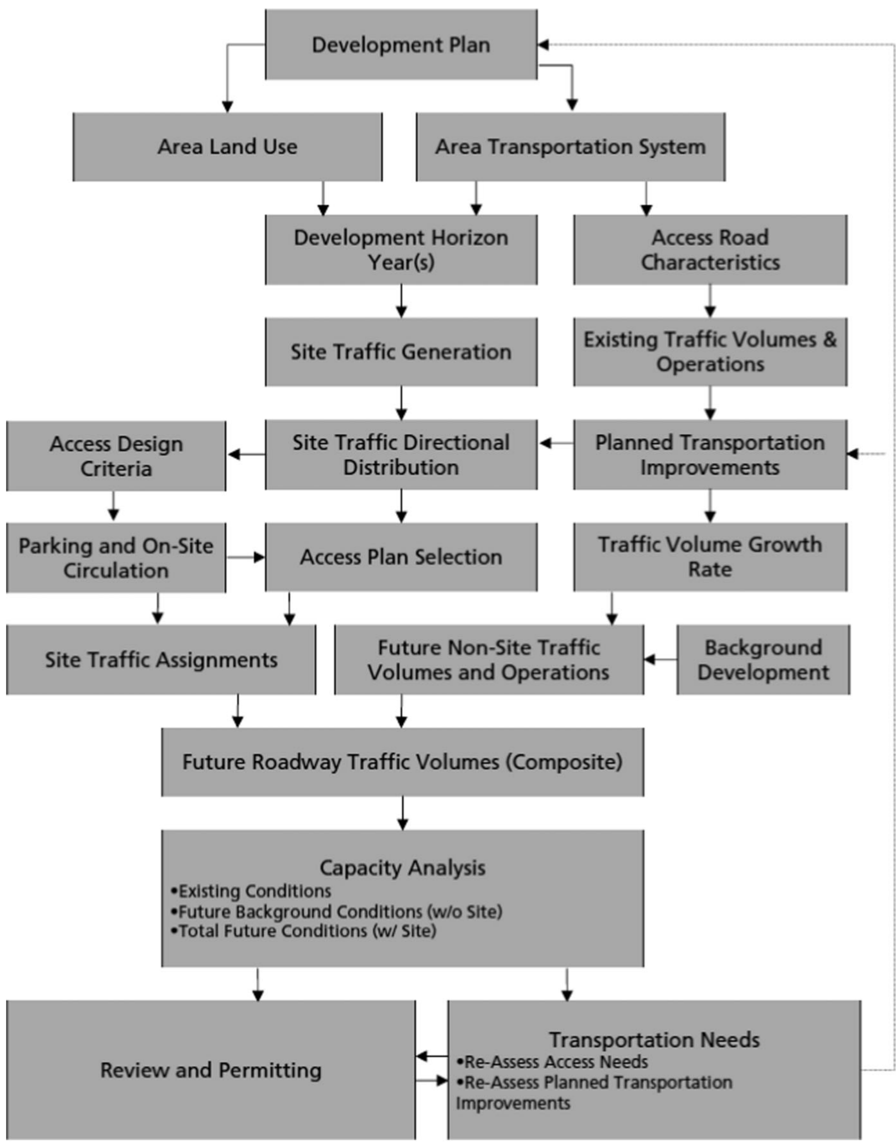


Figure 1.2 ITE traffic impact analysis process (*3*).

other sources must also be predicted, which could include pass-by and internal trip reductions. The amount and distribution of new traffic will play a major role in determining any necessary geometric upgrades, including intersection design. In order to pay for geometric upgrades, traffic impact fees may be implemented. The many facets of a TIA require open communication and coordination between the parties involved in order to produce a high-quality analysis. Many of these topics will be discussed further in this report.

1.3 The Updates

Twenty years have passed since the publication of the manual and guides, and now INDOT has a desire to look back to see how they have performed in the past. To what extent are the guides being used in the INDOT districts? What do consultants and reviewers think about how the guides have worked? By analyzing the use of the guides and comments regarding them, it is hoped that the guides can simplify the analysis process for both applicants and reviewers. Also, because many changes can occur over a twenty-year time span, it is reasonable to determine what changes may have taken place in (a) the issues addressed by traffic impact analysis and (b) traffic impact analysis methods. As issues arise, appropriate investigation and evaluation will be undertaken to determine the needed updates to the manual and guides.

2. OVERVIEW OF RELATED LITERATURE

As traffic impact analysis (TIA) came to be practiced throughout the United States, numerous guides, manuals, and standards have been published. This chapter presents pertinent publications and provides a brief description of how each one may impact the TIA process in Indiana.

2.1 Principal Nationwide References

In October 2012, the Institute of Transportation Engineers (ITE) released the *Trip Generation Manual* (9th edition). This document is used to estimate the number of vehicle trip ends generated over a specified time period by a proposed development. The data supporting the estimates have been collected and shared with ITE by transportation engineers and planners in many parts of the US (*4*). In its current format, the *Trip Generation Manual* consists of three volumes. Volume 1 is a 154-page "User's Guide and Handbook," which provides guidance on the proper use of the data in Volumes 2 and 3. The Handbook—formerly a separate publication (*5*) but now part of Volume 1 (*4*)—provides information on issues of importance that arise when estimating trip generation. These issues include pass-by and diverted-link trips, multi-use developments, and other factors that may influence the actual amount of new traffic (*5*). The data in Volumes 2 and 3 are displayed on 2000-plus pages for hundreds of land use types. Despite this extensive resource, trip generation can be a challenging undertaking, even for common land uses such as shopping centers. A case study is included later in this report to illustrate the challenge.

In 2010 ITE published *Transportation Impact Analyses for Site Development: An ITE Recommended Practice* (*3*). This is probably the single most useful national reference. The purpose of the TIASD Recommended Practice is to:

> provide guidance for preparing and reviewing transportation impact analysis studies for new and expanding land developments. The report also encourages consistency in planning site access, on-site circulation and parking layouts and off-site improvements for new and expanding developments. … This report updates the transportation impact analysis guidelines provided in the earlier recommended practice to reflect changes in the state of the practice (*3*).

Because the ITE TIASD Recommended Practice is an excellent overview of the commonly accepted and implemented methods for traffic impact analysis, it is an important reference. The INDOT guides will not extensively replicate what is in the TIASD RP, but their contents will be consistent with it. The INDOT guides will focus on issues of concern to INDOT and local public agencies that have responsibilities related to TIA.

The 5th edition of the *Highway Capacity Manual* was published in 2010. The manual provides accepted methodology for assessing the operations and impacts of highway projects. Methodology is mostly multimodal in nature, allowing for the evaluation of operations for pedestrians, bicyclists and mass transit, as well as vehicular traffic (*6*). The manual's methodologies have been coalesced into a software package called Highway Capacity Software, with the most recent version being 2010 to coincide with the release of *HCM 2010*. The methodologies may be used to assess the operations of highways, urban segments and intersections, which would be used when conducting a TIA.

2.2 References in and for Indiana

In addition to its TIA guides, INDOT is governed by other manuals and guides that may impact how a TIA is conducted. Several documents have been published that establish standards, recommended practices or methodology to use when conducting a TIA. It is important to review other publications that may have an impact on a TIA in order to maintain consistent standards.

A major issue that affects the impact of a new development is the location of access points. AECOM created a guide entitled the *Access Management Guide* for INDOT to serve as a reference manual when determining proper placements for driveways. The guide is applicable for use by planners and other jurisdictional bodies as well. Proper placement of access points can provide improved traffic flow and reduced crash incidents compared with poor placement. Proper access control may also be used to preserve safe traffic operations at higher speeds on routes agencies desire to utilize as higher class facilities (*7*).

Provisions of the Indiana Code address the right of a property owner to have access to public roads. IC 9-21-19-1 has the heading "Permit requirements":

> Sec. 1. A person may not: (1) construct a private entrance, driveway, or approach connecting with a highway in the state highway system or the state maintained route through a city or town; or (2) cut or remove a curb along a highway;
>
> without a written permit from the Indiana department of transportation. The action must be in accordance with the rules and requirements of the department.

The *Indiana Design Manual* contains standards to be met when developing a site. One such standard is the minimum distance between signalized intersections on various classes of roadways (*8*). The Indiana *Driveway Permit Manual* contains geometric standards for driveways, as well as regulations for access control to protect through traffic on main-line roads from conflicting movements (*9*). These two manuals affect the location of driveway access and the type of traffic control at the driveway entrance, and therefore must be considered when conducting a TIA.

3. APPRAISAL OF THE 1992 GUIDES

3.1 Sources of Opinions

Over twenty years have passed since the 1992 Traffic Impact Analysis (TIA) guides were adopted by INDOT. The main goals of the current research are to evaluate the 1992 TIA guides and determine what changes are necessary. The researchers turned to a variety of individuals and groups to help in these making these assessments.

- Guidance from the members of the project's Study Advisory Committee (SAC). The SAC members were chosen so as to represent INDOT Central Office, INDOT Districts, local public agencies (LPAs), and consulting engineers.
- Conversations with individuals in local public agencies (cities, towns, and counties) who conduct (or have a stake in) Traffic Impact Studies. Some of these individuals were invited to the project's SAC meetings.
- Researchers attended meetings of the LPA groups that were held as part of the annual Purdue Road School. At these meetings, the researchers were given the opportunity to explain the project's aims to those in attendance. Each group agreed to help the researchers distribute a survey to gauge the extent to which the 1992 guides were being used, and what improvements would help LPAs in using the TIA process.
- Chet Skwarcan of Traffic Engineering, Inc. had begun a survey of INDOT districts for possible use in a presentation at Road School. When that presentation was not possible, Mr. Skwarcan very graciously shared his preliminary survey results with the researchers for this project.
- Whenever the opportunity arose, such as at breaks in a conference or at a meeting of the Indiana Local Technical Assistance Program, the researchers asked those individuals with experience in TIA to offer their advice and suggest case studies.
- A survey was sent through a contact person at each LPA group to selected members of those groups. The survey was also sent to selected members of the consulting engineering community through the consultant representative on the SAC. The survey and responses may be seen in Appendix A. The survey results are discussed later in this chapter.

3.2 User Comments on the 1992 TIA Guides

On the whole, users of the guides say they have provided a good basis for conducting and reviewing Traffic Impact Studies. A number of jurisdictions and consulting firms in Indiana continue to refer to and use either the Reviewer's or Applicant's Guide (*2,10*). However, some entities surveyed were not aware that the guides existed. This was true for some INDOT personnel, some consulting firms, and a lot of LPAs. One of the goals of this project was to make the updated guides applicable to local agencies such as cities and counties, and to make these agencies aware that a reviewer's guide existed. This would be especially helpful when the actions of one jurisdiction regarding TIA could affect the roadway operations of a nearby jurisdiction.

In the sections below, comments about the 1992 Guides made by survey respondents are summarized. Comments made at meetings of the project's Study Advisory Committee are also included.

3.2.1 Positive Aspects of the 1992 Guides

The scoping meeting checklist found in Appendix A of both the Applicant's and Reviewer's Guides was the aspect most often cited as very useful. A few minor revisions and additions to the scoping meeting checklist are needed, however. These changes will be incorporated in the updated Applicant's Guide and Reviewer's Guide.

3.2.2 Suggested Improvements to the 1992 Guides

Although the 1992 guides have served INDOT well, the users and potential users of the guides offered some suggestions for how to make the guides more useful in addressing issues that arise under current conditions. These suggestions are listed briefly in this section. A more detailed discussion of these improvements will appear in later chapters of this report, and in the updated Applicant's Guide and updated Reviewer's Guide, as appropriate.

A. Require an executive summary at the beginning of the traffic impact study (TIS) report to lay out the findings of the analysis. This requirement will be emphasized in the Sample Report Outline in the updated Applicant's Guide and Reviewer's Guide.

B. More graphics within the report would more clearly convey findings and results from the TIS to reviewers and the general public. Reviewers and the public are more easily able to find and interpret results when they are presented in a table or overlaid on a graphical image. Examples will be included in the updated Applicant's Guide and Reviewer's Guide.
C. A preliminary review of the trip generation and trip distribution steps might prevent portions of the analysis having to be redone later in the TIA process. This activity will be included in the Scoping Meeting Checklist in the updated Applicant's Guide and Reviewer's Guide.
D. Regarding trip generation and trip distribution, the importance of using recent and accurate growth rates and traffic counts was stressed. Traffic counts and growth rates are covered in Chapters 3 and 4 of the *ITE Recommended Practice on Traffic Impact Analyses for Site Development* (*3*).
E. Some minor wording changes were also mentioned; specifically, it was suggested that the term "accidents" in the guide be changed to "crashes." In 1997, the National Highway Transportation Safety Administration began using the term "crashes" instead of the traditional term "accidents." This change was in recognition of the fact that most crashes have a cause and are not simply the result of uncontrolled circumstances. This change will be implemented in the updated Applicant's Guide and Reviewer's Guide.
F. INDOT uses a number of manuals to govern the design and operations of roads. Multiple commenters said that the TIA guides should be better aligned with the *Indiana Design Manual* and *Access Management Guide*. It was also suggested that some chapters in the *2010 Highway Capacity Manual* have methodology applicable to TIAs and should be referenced in the guides. Whenever possible, this report and the updated Applicant's Guide and Reviewer's Guide make references to the other pertinent Indiana manuals, the HCM, and ITE's *Recommended Practice on Traffic Impact Analyses for Site Development* (*3*).
G. Is it possible for software commonly used in a TIA to be referenced within the report? One individual suggested that the analysis section of the guides refer to *Synchro* as the primary analysis tool for intersections and progression. This is done in Section 4.5 of this report.
H. More than one respondent requested clarification of the distinction between a traffic operations analysis (TOA) and a traffic impact analysis (TIA). The distinction between a traffic impact analysis (TIA) study and a traffic operations analysis (TOA) study is addressed in Article 7, Rule 1, Section 2 of the *Indiana Administrative Code*:

105 IAC 7-1-2 Definitions

(34) "Traffic impact analysis study" means a specialized study of the impact a given type and size of new land use has or will have on a nearby public transportation system, that is prepared by or under the supervision of a registered professional engineer with experience in traffic engineering operations.

(35) "Traffic operations analysis study" means a specialized study of the possible traffic safety and operational problems a proposed development may have in the immediate vicinity of the development site due to a compromise in existing design standards caused by the development, that is prepared by or under the supervision of a registered professional engineer with experience in traffic engineering operations.

TOA is used to provide detailed level of service and delay measures as part of TIA.

I. Some individuals are unsure of who is to supply the crash data for TIAs and have requested that the responsible party be clarified. Section 4.3 of this report addresses the matter of traffic crash data.
J. Guidance was requested regarding access control, especially for the different tiers of roads in Indiana. Chapter 3 of the INDOT *Access Management Guide* (*7*) covers in detail the "tiered system of access categories." Table 3.1 of the *Access Management Guide* includes Design Standards regarding access by tier and type of road. "The spacing guidelines for unsignalized intersections and driveways are based on speed as specified in Table 8.1 of INDOT's *Driveway Permit Manual,* irrespective of tier" (*7*, p. 31). Details are also provided for Tiers 1, 2, and 3 regarding (*7*):

1. Type of access permitted (at-grade intersection, private driveway)
2. Traffic movements allowed (full movements, right-in/right-out only, etc.)
3. Traffic control devices permitted (traffic signal, STOP sign)
4. Spacing criteria for public intersections and driveways

Both the applicant and the reviewer should be aware of these criteria and have access to them.

K. A defined process or rates for both pass-by and internal trips should be referenced or provided in the guides. Pass-by trips are discussed in Section 4.1of this report and internal trips receive coverage in Chapter 9. Both updated guides will refer to these treatments.
L. When should a developer be asked to share in the costs of future improvements of the infrastructure surrounding the developer's site? This could be accomplished through traffic impact fees, which are discussed in Chapter 5.
M. At what point or distance does a signal not need to be included in the TIA evaluation process? This question can be interpreted in two ways. (1) Existing signalized intersections can be used to define the extent of the study area for TIA, using a table like Table 2.3 in ITE's *Recommended Practice on Traffic Impact Analyses for Site Development* (*3*). For example, a proposed shopping center with between 70,000 and 100,000 square feet of gross leasable area should have a TIA study that includes "all signalized and major unsignalized intersections and freeway ramps within one mile of a property line of the site. (2) If the question refers to warrants for a new signal at a previously unsignalized intersection, the updated Applicant's Guide and Reviewer's Guide will refer to the criteria contained in the ITE's *Recommended Practice on Traffic Impact Analyses for Site Development* (*3*), but caution that the criteria vary depending on jurisdiction, roadway type, and area conditions.
N. Several comments pertained to intersection design. This may have to be considered on a site-by-site basis, depending upon the surrounding transportation network and size of the development. Current design manuals may also provide guidance on this issue. Specific comments were:

1. Under what conditions would a roundabout be justified instead of a signalized intersection?
2. Provide details regarding alternative intersection designs, which would include roundabouts.

Roundabouts and innovative intersection designs are discussed in Chapters 6 and 7.

O. Who owns a TIA after it is submitted? SAC members recommended that language be added to the guides stating that, "Traffic impact study reports become public record upon submittal." This is based on the following points raised in discussion:

1. Because the data collected as part of the Traffic Impact Analysis is paid for by the public agency, the data become the property of the public agency.
2. If the consulting firm that collected the data wishes to use the data again for another project nearby, it is free to do so, as long as the data are still current and applicable.
3. If another consulting firm wishes to use the published data for another project nearby, it is free to do so, as long as the data are still current and applicable.
4. The "current and applicable" status should be decided at the initial meeting.
5. Any proprietary methods used by a consulting firm need not be described in detail in the Traffic Impact Study report, but the methods should receive the approval of the public agency at the initial meeting.

4. RECOMMENDED MODIFICATIONS TO TIA GUIDES

As indicated in the previous chapter, responses to the surveys covered a variety of topics. Guided by recommendations from the project's study advisory committee (SAC), the researchers focused on topics such as pass-by trips, traffic growth rates, traffic counts, crash data, traffic analysis software and traffic engineer credentials. These topics will be covered in this chapter. Other topics that were mentioned in the survey results or by SAC members are addressed in separate chapters:

- Traffic impact fees in Chapter 5
- Innovative intersection designs in Chapters 6 and 7
- Coordination between multiple jurisdictions in Chapter 8
- Internal trips in Chapter 9

4.1 Pass-By Trips

4.1.1 Definitions

In trip generation, each vehicle trip that arrives at a development can be classified as *primary*, *diverted*, *or pass-by*. (Figure 4.1 is Figure 5.1 in (*5*) and (*11*).) Traffic that does not enter or exit the site is considered *background traffic*.

A pass-by trip is a trip that would have been on the roadway passing the new development's site, whether the development was in existence or not. The definition in the ITE Trip Generation Handbook (*4,5*) is as follows:

> Pass-by trips are made as intermediate stops on the way from an origin to a primary trip destination without a route diversion. Pass-by trips are attracted from traffic passing the site on an adjacent street or roadway that offers direct access to the generator. **Pass-by trips are not diverted from another roadway.**

Primary and diverted trips attracted to the new development's site add to the number of vehicles on the roadway; the pass-by vehicles do not. However, all three trip types—even the pass-by trips—involve vehicles turning into and out of the development's site, adding traffic conflicts at the access points. If the vehicle shown making turning movements A and B in Figure 4.2 would have been on the street shown in any case, but the driver chooses to patronize the new shopping center, no new traffic has been added to the street. However, the number of traffic conflicts has been increased. If the driver making turning movements C (into the Gas Station) and D (out of the Gas Station) would have made the right turn at the intersection if the Gas Station were not there, the introduction of the Gas Station has diverted the driver from using the intersection, but has caused traffic conflicts at the driveways.

4.1.2 Pass-by Trip Data Collection

The three types of trips are easy to define, but they are not easy to document. A vehicle entering an existing site cannot be easily categorized as primary, diverted, or pass-by. The best way to determine the trip type is to ask the driver, but this is tedious and intrusive. During the 1991 study (*1*), such a personal interview survey was carried out at the same time that a license plate survey was being done at the same small shopping center in Lafayette IN. The license plate survey data were used to approximate the results from the personal interviews. The estimates of pass-by trips were so good, that the experiment was repeated at a small shopping center in Indianapolis IN. Again, the license plate survey was able to produce a very good estimate of percent pass-by trips. The license plate method is described in Chapter 3 of the 1992 INDOT Manual (*1*). Section 5.6 of the ITE Trip Generation Handbook (*4,5*) sets out an interview-based survey that is similar to the customer survey used in 1991 for JHRP Project HPR-2039.

4.1.3 Estimating Pass-by Trip Percentage at a New Development

Section 5.4 of the 2012 ITE *Trip Generation Manual* (*11*) contains a database with pass-by percentages for several types of retail developments. The pass-by percentage equation for retail/shopping center during the weekday PM peak period is an exponential

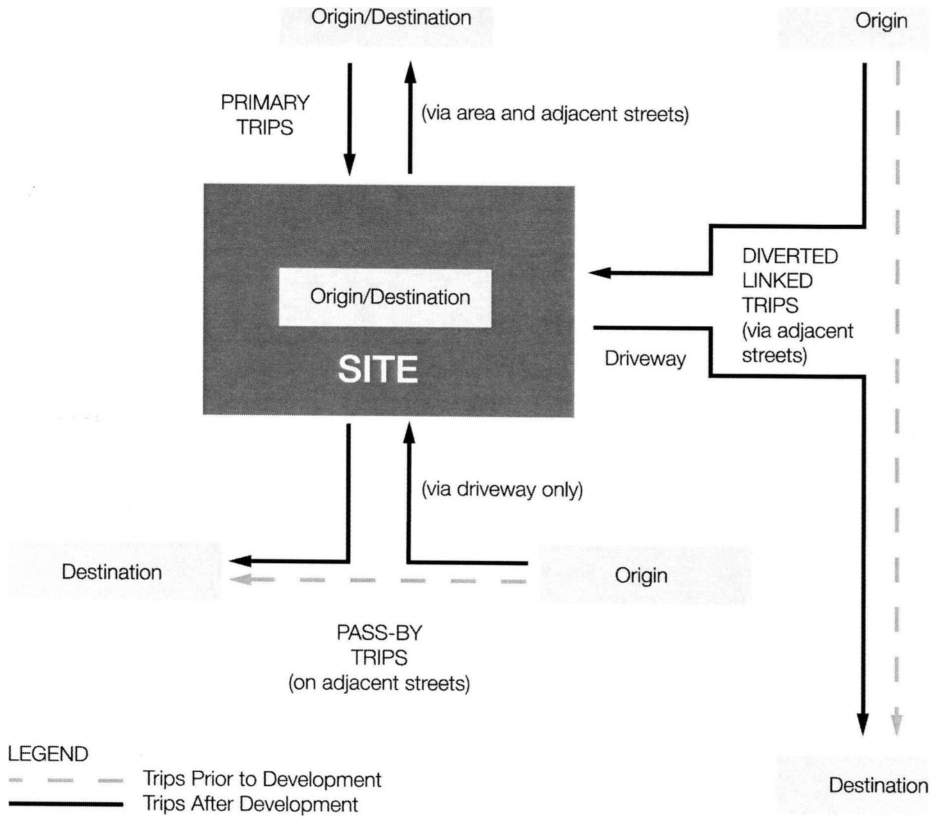


Figure 4.1 Types of trips (*4,5*).

function. (See the first equation in Table 4.1.) The variable X is the size of the development, in thousands of square feet of floor space. Lan (*12*) focuses on ITE's retail/shopping center equation, pointing out that its exponential form may lead to over or underestimating pass-by trip percentages when extrapolating outside the lower limit (X = 9) and upper limit (X = 1200) of the independent variable. Lan developed new equations from the ITE database using nonlinear least squares (NLS) for retail/shopping center pass-by trip percentages. (See Table 4.1.) The computed values of P at X = 9 and X = 1200 are shown in Table 4.1.

It appears that Lan's concern about overestimating percent pass-by trips is justified only for very low values of X, where the lowest number of trips occur. As Figure 4.3 shows, any of the three equations in Table 4.1 are reasonable bases for estimating P for moderate values of X, given the wide scatter in the data collected at various locations for *percent pass-by trips*.

4.1.4 The Pass-by Trip Assignment Process

Section 5.2 of the ITE Trip Generation Handbook (*4,5*) demonstrates the steps involved in estimating the number of trips added to the traffic volume on a street adjacent to proposed shopping center, along with the associated turning movements into and out of the site.

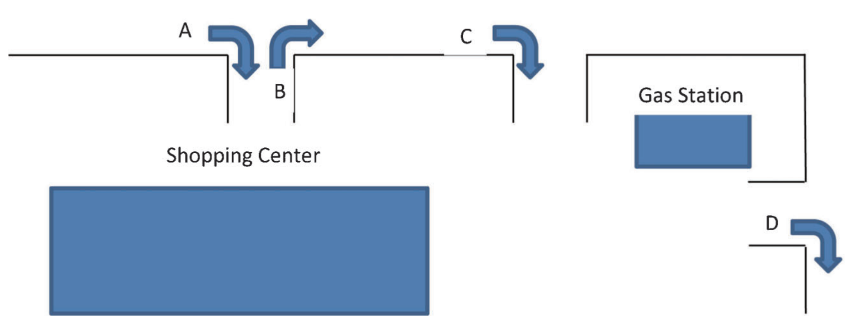


Figure 4.2 Pass-by trip and traffic conflict points.

TABLE 4.1
Pass-by trip equations for shopping center, weekday PM peak

	P = pass-by trip percentage	P at X=9	P at X=1200
Original ITE equation (*10*)	Ln(P) = -0.29 Ln(X) + 5.00 R^2 = 0.37	78.5	19.0
Re-estimated ITE equation using nonlinear least squares (*11*)	P = 129.18 $X^{-0.252}$ R^2 = 0.344	74.3	21.6
Lan equation using nonlinear least squares (*11*)	P = 20.93 + 33.16*0.996^X R^2 = 0.336	52.9	21.2

An annotated overview of the steps is given in Figure 4.4.

4.2 Primary Sources of Trip Generation Data

Primary data are collected by the analyst for a specific purpose. Data obtained from other sources, such as ITE, are called *secondary* data. Normally, secondary data have the advantage of being based on a larger sample size than can be acquired with reasonable time and expense for a specific project. The drawback of secondary data is that they may have been collected at locations that do not replicate the particular site that is the subject of a TIA. For example, secondary data in the *Trip Generation Manual* (*11*) for a proposed Fast-Food Restaurant with Drive-Through Window are based on 132 studies. It is probably not worth the time and expense to collect trip generation data at enough local Fast-Food Restaurants with Drive-Through Window to replace the secondary data, unless the trip rates do not seem to fit the case at hand. If some local data are available, however, they can be combined with secondary data to improve the data.

Let us say that the ITE average trip rate for a particular land use is T_0 = 26.451 with standard deviation s_0 = 22.85, based on n_0 = 120 observations. These are secondary data. Local (primary) data have been collected at n_1 = 30 sites, with T_1 = 20.25 and s_1 = 15.5. An updated value of T_u can be estimated using the Bayesian equation (*13*)

$$T_u = \frac{n_0 s_1^2 T_0 + n_1 s_0^2 T_1}{n_0 s_1^2 + n_1 s_0^2} \quad (4.1)$$

$$= \frac{(120 * 15.5^2 * 26.451) + (30 * 22.85^2 * 20.25)}{(120 * 15.5^2) + (30 * 22.85^2)} = 24.27$$

and an updated value s_u for the standard deviation of the data

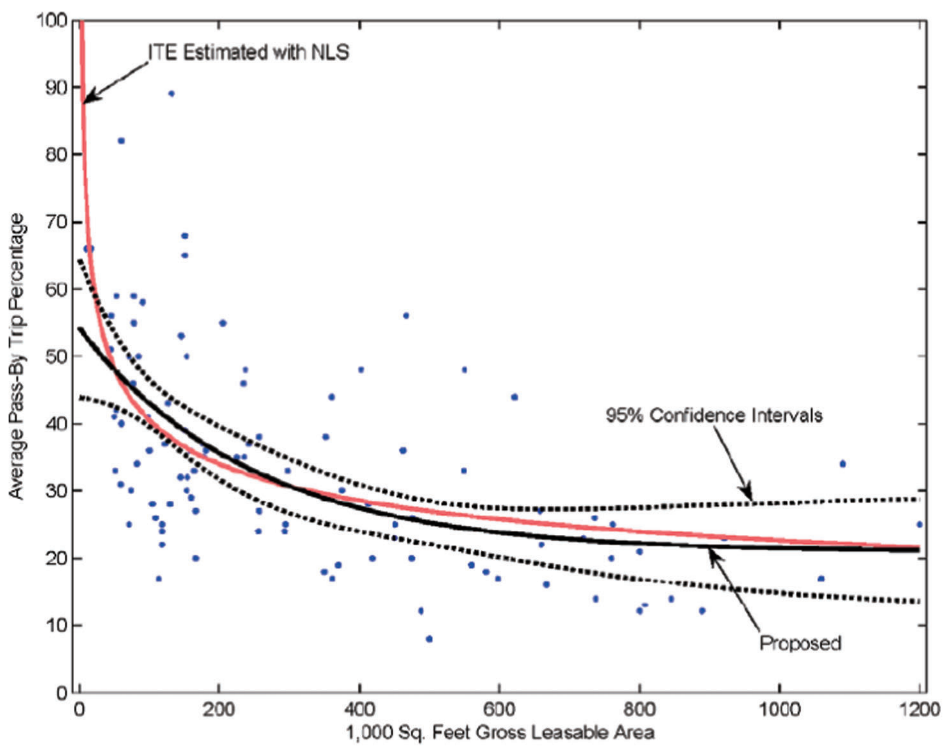


Figure 4.3 Comparison of ITE and Lan's proposed pass-by percentage equations (*11*).

A. **Base Volumes.** Indicate the Base Volumes (each direction) on the adjacent street at each proposed driveway. (There may be more than one driveway or access point for a development.) At the driveway shown in Figure 4.4A, the traffic is 200 vph eastbound and 1000 vph westbound. The Base Volume is the traffic that would occur *without* the new development, and is usually for the peak hour and the year in which the development will open, or be built out, whichever is specified.

B. **Site Generation.** Estimate and allocate the Trip Ends predicted for the site to each of its driveways. In this example, 2000 evening peak hour trips are predicted, 20 percent of which (or 400) will use the driveway shown in Figure 4.4B. Using an equation such as those in Table 4.1, estimate the pass-by trip percentage for the site. Apply this percentage to each driveway. Here, 15 percent of 400 = 60 pass-by trips.

C. **Non-Pass-By Trip Pattern.** At each driveway, assume a pattern for non-pass-by trips. What percentage of these trips will come from each direction? What percentage of these trips will depart in each direction? Here, 80 percent of the non-pass-by trips are expected to arrive from the east and the other 20 percent from the west. Although it is not always the case, here all the non-pass-by trips are expected to leave in the direction from which they came, or at least the percentages will be the same.

D. **Pass-By Trip Pattern.** At each driveway, assume a pattern for pass-by trips. What percentage of these trips will come from each direction? What percentage of these trips will depart in each direction? Here, the Base Volumes are used as a guide: The 1000 vph WB volume is 83 percent of 1000+200 and the 200 vph EB volume is 17 percent of 200+1000.

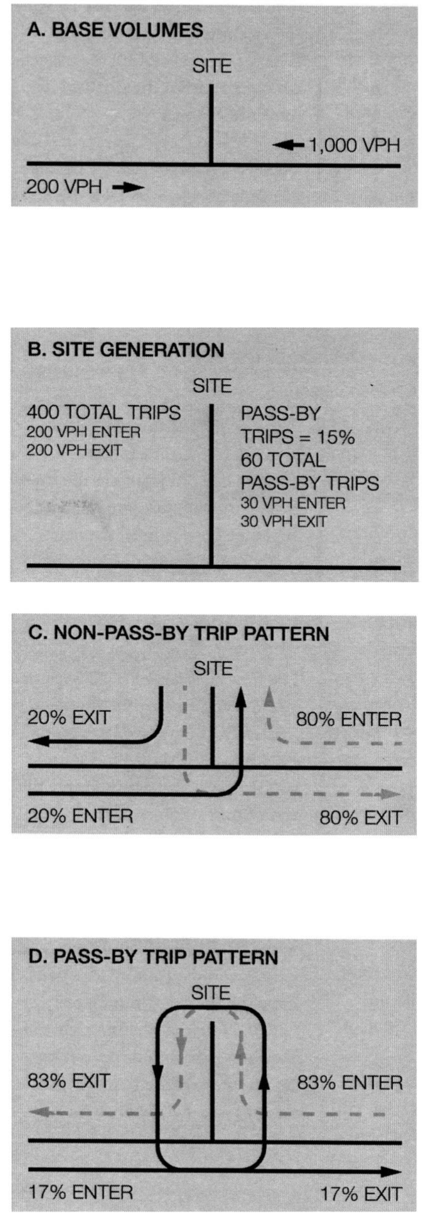


Figure 4.4 Application of pass-by trips (*4,5*). (Figure continued on p. 10.)

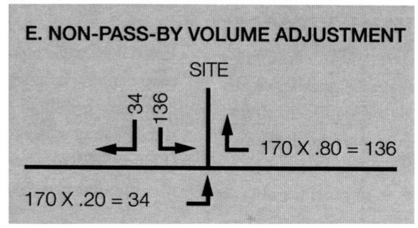
$$s_u^2 = \frac{s_0^2 s_1^2}{n_0 s_1^2 + n_1 s_0^2} = \frac{22.85^2 * 20.25^2}{(120 * 20.25^2) + (30 * 22.85^2)} = 2.81 = 1.68^2 \quad (4.2)$$

Page 23 of the ITE *Trip Generation Handbook* (*4,5*) shows how to implement another way to combine national and local trip generation rates. The ITE method is easier to use, but if the national sample size is much larger than the local sample size (as it often is), the ITE method is not worth using. The Bayesian Method takes into account the standard deviations of the national and local samples. Bayes gives the local sample some weight without giving it too much influence.

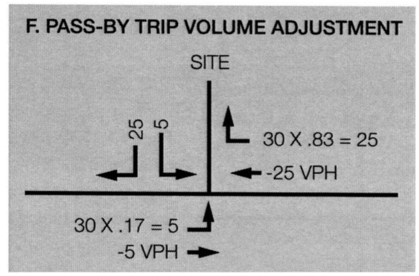
4.3 Growth Rates and Traffic Counts

Besides the three types of traffic that will come to the new development, *background traffic* volumes must be known as part of a traffic impact study (TIS). Background traffic (or non-site) traffic is traffic that would have occurred in the absence of the new development. In the short term, it is necessary to know the non-site traffic in order to properly assign the traffic impacts of the development as part of all traffic in the vicinity. A bigger challenge is to forecast changes in traffic because of the site (especially if it is to be developed in phases) and because of changes to non-site traffic. In both the short term and the long term, the concern is the level of service on the streets and at intersections near the development.

E. **Non-Pass-By Volume Adjustment.** At each driveway, subtract pass-by trips from total trips, then apply the directional distribution found in Step C. Example for WB turn into site: 200 trips enter – 30 pass-by entries = 170 non-pass-by-trips entering. 80 percent (from Step C) of 170 = 136. The result is usually four values – the number of non-pass-by vehicles entering and exiting the driveway from/to each direction. Based on the directional distribution assumed in Step C, the turning movement volumes are symmetrical.



F. **Pass-By Volume Adjustment.** At each driveway, take the results from Step B and apply the directional distribution found in Step D. 30 entering pass-by trips * 83 percent from the east = 25 vph from the east. The result is usually four values – the number of pass-by vehicles entering and exiting the driveway from/to each direction.



G. Final Volumes. Add the turn volumes from Steps E and F. Trips entering = 136 + 25 = 161 from the east and 34 + 5 = 39 from the west. Convert the Base Volumes to account for non-site and site traffic movements. For the WB Base Volume, 1000 – 25 = 975 accounts for the pass-by traffic (25 vph) that would have been there, even without the new shopping center, but is now part of the 161 trips entering the site.

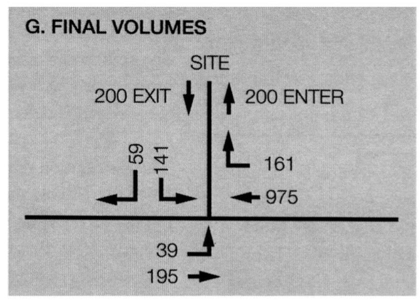


Figure 4.4 Continued.

Predicting changes in traffic patterns several years into the future can be very difficult. The local economic patterns can change significantly due to local and/or global factors, causing a change in growth rates and patterns. Over time, traffic patterns may also change due to changes in the local economy and/or the local infrastructure. The most up-to-date traffic counts available should be used. Consultants and INDOT or local agencies should communicate as to what growth rates and traffic counts are acceptable to ensure an accurate analysis. It may also be possible to use the long-range plan for the community if it is served by a metropolitan planning organization. Chapter 4 of the ITE Recommended Practice (*3*) goes into some detail regarding "Non-Site Traffic Forecast."

4.4 Crash Data

Sometimes when conducting a TIA, there are locations within the study area that experience high crash rates or an usual number of specific crash types. For these locations, a safety analysis may be warranted and should be included in the TIA. The ITE Recommended Practice (*3*) suggests that an intersection with a collision rate of more than one per million entering vehicles may be worthy of additional analysis, subject to consultation with the appropriate agency.

In Indiana, crash data are collected by law enforcement agencies and compiled into an Automated Report and Information Exchange System (ARIES) database by an independent contractor. Data summaries down to the county level are available at the Indiana Criminal Justice Institute (ICJI) website, but data at the level of detail needed for a TIA are contained in ARIES. The data from this database are provided to public agencies such as INDOT, but must be purchased by private individuals and firms. When a safety analysis is needed as part of a TIS for INDOT, a question arises: Should INDOT provide the ARIES data to the firm conducting the TIA, or should the firm be required to purchase the ARIES data?

As this report is written, INDOT's policy is to require the applicant to purchase the crash data needed for the analysis directly from the ARIES vendor. INDOT is concerned that, by providing the crash data, INDOT becomes liable for the age and accuracy of the data. By requiring the applicant to purchase the data, the TIS preparer can decide what data (and how much) are needed for the TIS. The need for a safety analysis should be discussed with the governing jurisdictions at the scoping meeting.

4.5 Credentials

According to a survey of INDOT districts, the quality of a traffic impact study produced by engineers not licensed in Indiana tends to be lower than that of traffic engineers licensed in Indiana. Based on feedback from a survey conducted of INDOT district engineers who review TIAs, two main factors were mentioned that are believed to most often be causes of lower quality TIAs. Those two factors were a lack of understanding of what reviewers in Indiana expect in a TIA report and unfamiliarity with local conditions. It was thought that perhaps stricter licensing requirements may improve the quality of TIA submissions.

Regulations exist governing who may conduct engineering work in Indiana. In order for a professional engineer to stamp and certify plans for a public project in Indiana, he/she must be licensed in Indiana (*14*). This may be accomplished in one of two ways. The engineer can obtain licensing in the State of Indiana by going through the application process for professional licensure. The other way would be by obtaining comity registration. Comity registration is for engineers registered in another state wishing to become registered in Indiana. The comity process ensures that engineers applying for registration have met similar requirements for licensing as those in Indiana (*14*). Approved registration by either method permits licensed engineers to practice and approve project plans within Indiana.

It has been suggested that perhaps a professional traffic operations engineer (PTOE) license should be required for conducing TIAs in Indiana. This would, however, prevent a number of professional engineers licensed in Indiana without a PTOE license who have produced high-quality TIAs in the past from conducting TIAs, and it is not wished to exclude these engineers. Requiring an engineer conducting a TIA in Indiana to have a PTOE license may require some form of legislation or promulgation. This could be pursued at a future date, if INDOT deemed it necessary. At this point in time, it would be best to not require a PTOE to conduct TIAs.

4.6 Citing Software

When analyzing a network to determine the impacts of newly generated trips, some sort of analysis software is often needed. When the report for a TIA is prepared, the software packages used in the analysis should be clearly identified in the report. At the scoping meeting, it would be helpful to the reviewing agency if the applicant would mention what software was likely to be used during the TIA. If the reviewer is unfamiliar with the software to be used, the software's capabilities and limitations could be explained at that time, along with a reason for choosing that software. Assumptions and default values should be clearly stated, and results should be examined for reasonableness.

Some software packages commonly used in TIA are listed below in the left-hand column of Table 4.2. In the right-hand column, additional computer software packages "designed to undertake a wide variety of capacity analyses … including signalized intersections:" are taken from the ITE Recommended Practice (*3*). In both columns the software packages are listed in alphabetical order. This is not a complete list, nor is the software given in order of preference. These are simply software packages that have commonly been used for traffic analysis in Indiana. Some firms may use software developed in-house and new software packages may become available at any time. Many of the computer software packages listed can be used for analysis of signalized intersections and unsignalized intersections (*3*).

A new cloud-based software called Online Traffic Impact Study Software (OTISS) has recently been developed jointly by Transoft Solutions and ITE. It is billed as the "The *Future* of Traffic Impact Analysis" and it is planned to eventually include all of the steps of a TIA in the software (*15*). Currently, OTISS is able to conduct the trip generation analysis and trip distribution components of a TIA using the data from the 9th edition of the *Trip Generation Manual.* (*11*) OTISS will need to be evaluated before being accepted for use in TIAs.

4.7 Median Matters

In some cases, a new development causes questions to arise regarding a median. Two common examples are:

A. Should an existing median opening be closed to prevent unsafe left turns into a new development? See Figure 4.5.
B. Should a new median opening be created to permit left turns into a new development? See Figure 4.5.

There are legal and operational issues that affect the answers to Questions A and B above.

4.7.1 Legal Issues Affecting Traffic Impact Analysis

On the legal side, Technical Report #1, Indiana Statewide Access Management Study, Access

TABLE 4.2
Software for TIA

Arcady	AIMSUN
Highway Capacity Software	CUBE DYNASIM
Rodel	Paramics
SIDRA	PASSER II-02, PASSER V-03, PASSER III-98
SimTraffic	SIGNAL 2000
Synchro	SIG/Cinema
TransModeler	TEAPAC
TSIS (CORSIM)	TRAFFIX
VISSIM	TRANSYT-7F

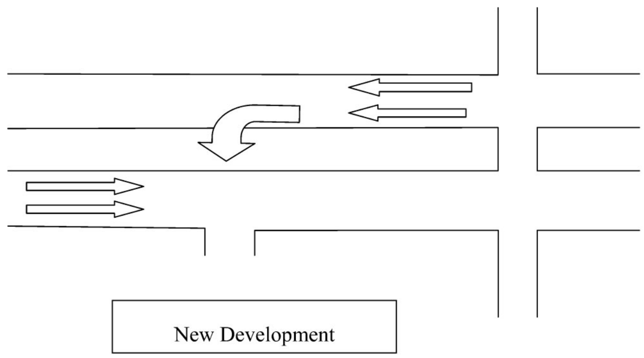


Figure 4.5 Should left turns across the median be permitted?

Management Authority in Indiana (*16*) offers several helpful court cases. Excerpts taken from the Report are presented below.

- Establishing divided highways where U-turns and left turns are permitted only at designated points by either physical dividers or regulations have been consistently upheld as reasonable based on the principle that an abutter has no property right in the continuance or maintenance of traffic flow past his property. The Indiana court in *State v. Ensley* applied the conventional principle that there is no property right in the free flow of traffic past the property of an abutter to address the impairment of access caused by the creation of a divided highway.
- "At issue in the Indiana case *State v. Cheris* was whether the construction of a median strip resulted in an impairment in the unrestricted flow of traffic past the abutting property or whether it resulted in a material and substantial interference of the abutting property holder's right of access." The court held that, because property holders "have no property right in the free flow of traffic past their premises, the construction of the divider strip does not deprive them of any property right, and, hence, any damage sustained thereby, by loss of business or depreciation in the value of their property, would not, for this further reason, be compensable."
- In *Indiana Dept. of Transportation v. Southern Bells, Inc.* … INDOT [had] proposed a median that would prevent southbound traffic from turning onto the access road to reach Southern Bells' business. The business obtained a temporary injunction, enjoining the INDOT road improvements. The court found that INDOT established a valid public purpose for the median construction, namely, public safety. Increased traffic created by a development project made the median necessary to protect public safety. INDOT "had a legitimate public purpose in constructing the median." Given the legitimate public purpose, if and to the extent INDOT's actions constituted any taking of Southern Bells' property interests, remedy was available through a suit for inverse condemnation under Ind. Code §32-1-1-121. The court referred to Ind. Code §8-23-2-4-1 in holding that INDOT's median is an action for which there is express legislative power and responsibility to perform.

The court cases cited above specifically address Question A above. Although no case could be found that addresses Question B, the same legal principles would seem to apply. INDOT has the legal authority to either introduce or close a median opening (*7*, p. 26), as long as INDOT is using the authority granted it by IC 9-21-4-2 to "maintain traffic control devices … and specifications upon all state highways" to (under IC 8-23-4-8) "promote public convenience and safety."

4.7.2 Operational Issues

Just because something is permitted under the Indiana Code, does not mean it is the best solution to a traffic access problem. With the growing use of traffic microsimulation software, several proposed geometric and traffic control device solutions can be evaluated against each other and against reasonable standards for delay and level of service. Use of one traffic microsimulation software package is demonstrated in Chapter 7 of this report to evaluate and compare several non-traditional intersection designs.

5. TRAFFIC IMPACT FEES

Traffic impact fees (from here on called *impact fees*) have spread across the United States, especially as transportation project costs have increased while the revenue received from gasoline taxes has decreased (*17*). Communities are using impact fees as a one-time revenue source to mitigate the costs incurred from upgrades to the transportation network needed due to increased traffic from new developments. Impact fees have also been used to pay for other community upgrades, such as new police and fire stations, new or improved park areas and ambulance service expansions (*17*). This report will focus strictly on traffic impact fees, which are of primary concern to the Indiana Department of Transportation (INDOT).

5.1 Indiana Impact Fee Law

Indiana passed legislation in 1991 that allows communities to use impact fees. The regulations governing impact fees may be found in the Indiana Code (IC) 36-7-4-1300 series (*18*). A number of restrictions are in place on the use of impact fees to avoid their misuse. A zone encompassing the contiguous area to which the impact fee is applied must be determined and improvements must uniformly benefit development in this area. Once the area is defined for which the impact fee will apply, the governing body must create and adopt a comprehensive plan for development in the area to be affected by the impact fee. With the comprehensive plan in place, a committee must be formed of five to ten members. Of the committee members, 40 percent must be representatives of the building, real estate or development industries. If such a committee existed before the plan was adopted, they may serve as the advisory committee as long as the committee member requirements are met (*18*).

The advisory committee is charged with determining an equitable and proportionate way of distributing the impact fee for different uses throughout the affected zone. The impact fee must have an explicit formula that would allow a developer to easily calculate what he/she would need to pay (*18*). For example, in the City of Fishers' code of ordinances, subchapter 156.42 explicitly sets the road impact fee to be $237.03 per 24 hour trip. The 24-hour trips are to be calculated using the most recent edition of the ITE *Trip Generation* report (*4*). The fee is usually paid when the structural building permit is issued, with a few exceptions, but a system must be in place that would allow developers to pay in installments. Improvements that do not require additional infrastructure cannot have the fee levied against them. The amount of impact fee levied on a zone must only be enough to cover improvements to bring the transportation system up to the levels of service prior to the development, not to community-desired levels of service. Collections from the impact fee are to be deposited in a special fund, with any interest earned from the collections deposited back into the fund (*18*).

Certain time limits exist regarding impact fees. Fee payers are entitled to a refund with interest if the infrastructure agency fails to complete any part of the improvements for which the fee was paid in a reasonable amount of time or 6 years after the issuance of a structural building permit. Impact fees have a finite lifespan. Indiana Code limits the length of time an impact fee can be in effect to five (5) years. The impact fee may be continued, but in order to do so, it must be renewed or replaced (*18*). No explicit language was found limiting the number of times an impact fee could be renewed/replaced.

5.2 Traffic Impact Fee Use in Indiana

A very small number of communities in Indiana have enacted traffic impact fees. Other communities have used impact fees for parks. Fishers, Noblesville, Zionsville and Westfield on the northern side of Indianapolis have used impact fees for road improvements (*19*). Fishers also enacted a bridge impact fee beginning in 2011. The fee is to be used to cover bridge project costs that used to be handled by Hamilton County. The bridge impact fee will be $22.96 per trip generated in a 24-hour period (*20*). While Fishers appears to be having success with its impact fees, the city of Zionsville was not successful with its parks and recreation impact fee enacted in 2005. The advisory committee set up for the impact fee recommended to the plan commission that the fee be set at $1,054 per lot. The plan commission, however, increased the recommended fee to $1,862 per lot based upon a "national average." This increased amount was adopted by the Zionsville Town Council. Consequently, the Builder's Association of Greater Indianapolis (BAGI) asked the courts to rule the impact fee ordinance invalid. The court found in favor of BAGI, saying the Zionsville impact fee ordinance violated provisions of Indiana Code regarding impact fees (*21*). Zionsville ended up having to pay back around $337,000 in fees it had collected.

5.3 A Legal Basis for Traffic Impact Fees

Zionsville's problem was that its impact fee was not proportionate. According to Powell, Stringham and Estill, "Contemporary U.S. law suggests that fees be based on a rational nexus of costs and benefits and on rough proportionality of a fee with the external cost imposed by new development" (*22*). The word nexus is synonymous with connection. Therefore, the law essentially means a rational (or logical) connection should be able to be made as to why the impact fee should be applied to a development, and the amount of a fee applied to a development must be proportional to that development's impact on the infrastructure or facility for which the fee is being applied. Powell, Stringham and Estill's main theme in their report is that it is very difficult to equitably implement impact fees that cover exact marginal impacts by a development. They suggest the privatization of all roads, as has been done already for some expressways through the use of tolling and in some gated communities where the community is responsible for the care of its internal roads (*22*). By doing this, they say impact fees could be eliminated and the new privatized roads would more equitably distribute the burden of maintenance and improvements to road networks.

When an impact fee is imposed on a development, it is still open for negotiation with the imposing government entity. Instead of paying some or all of an impact fee, some developers/owners will provide in-lieu contributions or dedications. These contributions could come in the form of donated land for future infrastructure expansion or the developer paying for the construction of additional infrastructure, for example. If a developer in Indiana provides a contribution/dedication, the developer/owner is entitled to a credit against the impact fee (*18*). The amount of credit would be based on the fair market value of the land or infrastructure provided, or the construction cost of the infrastructure, which would be determined by the developer/owner and the applicable infrastructure agency (*18*). Improvements in infrastructure in such a situation should be reviewed by the infrastructure agency to ensure compatibility with the agency's regulations and transportation plan and that the land is in a suitable location before approval of credit.

While the information in this report details many of the major requirements in order for a government body to adopt an impact fee, it is not comprehensive. Other requirements and many fine details must be met before an impact fee is adopted, so careful attention should be paid to the statutes in the Indiana Code. Current Indiana law is non-limiting concerning what public infrastructure projects impact fees can be used to fund. As this is similar in other states, it is recommended that the law remain as is, which will allow communities to decide what public infrastructure they would like to use impact fees to fund.

During the course of the literature review regarding traffic impact fees, no cases were found regarding the use of such fees by state agencies. All forms of local public agencies across the country have utilized impact fees. Use of traffic impact fees by INDOT likely would be the first use of such fees by a state agency, if INDOT saw it necessary to implement them. The Indiana Code would likely need revising in order to allow INDOT to use traffic impact fees, as well as to govern and ensure proper usage of the fees.

While impact fees provide a benefit to public agencies by providing additional revenue to use in maintaining their road infrastructure, the impact fees may also have a negative effect. As the amount of the impact fees increase, it becomes more of a burden upon developers and may discourage some new developments from taking place (*20*). Therefore, public agencies, particularly municipalities, must be careful when deciding to implement an impact fee. Fast-growing municipalities would be better suited for impact fees because the demand for development would justify private contributions to infrastructure improvements that would also increase the chances of success of those developments.

5.4 The Fishers Impact Fee Ordinance

The Fishers impact fee ordinance is eight pages long. The title of each (sub)chapter is given below, along with excerpts and paraphrasing that give a brief description of the contents of the ordinance.

§ **156.40 ESTABLISHMENT OF IMPACT ZONE** for developments meeting the requirements set forth in IC 36-7-4-1322(g), which specifies the conditions under which an impact fee may not be assessed against a development.

§ **156.41 ZONE IMPROVEMENT PLAN.** As a precondition to the adoption of this subchapter, the Town Council undertook a comprehensive and detailed traffic impact analysis. The TIA estimated the nature, location, sequencing, and timing of the road and street thoroughfare requirements and costs necessary to provide a specified level of service for the nature and location of development that is expected within the Impact Zone during the next ten years.

§ **156.42 ESTABLISHMENT OF ROAD IMPACT FEE.** In March 2010, the Town Council established the cost per 24-hour trip as $237.03, with the number of 24-hour trips based upon calculations taken from the ITE Trip Generation report.

§ **156.43 CREDIT IN LIEU OF PAYMENT; EXEMPTIONS.** Any person or entity obligated to pay a fee … shall have the option of financing, constructing and dedicating road and street thoroughfare infrastructure … in accordance with the road and street specifications for such road or street.

§ **156.44 IMPACT FEE DUE UPON ISSUANCE OF STRUCTURAL BUILDING PERMIT.** If the amount of the fee is greater than $5,000, an installment plan may be requested by the applicant in accordance with IC 36-7-4-1324 (a), (b), (c) and (d).

§ **156.45 LIEN RIGHTS ESTABLISHED.** Pursuant to IC 36-7-4-1325, the town acquires a lien against the real estate which is the subject of the impact fee.

§ **156.46 FORM OF RECEIPT.** The Town Clerk-Treasurer shall issue a receipt for any and all impact fees collected.

§ **156.47 APPEALS.** Any fee payer who believes itself to be aggrieved by the calculation of the impact fee may appeal from such calculation to the Fishers Impact Fee Review Board.

§ **156.48 ESTABLISHMENT OF ROAD AND STREET THOROUGHFARE FUND.** This fund and shall receive fees collected for the purposes set forth in this ordinance.

§ **156.49 USE OF IMPACT FEES COLLECTED PURSUANT TO THIS SUBCHAPTER.** Primarily, paying the capital costs of a new road and street infrastructure that is necessary to serve the new development that is identified in the Zone Improvement Plan.

§ **156.50 ESTABLISHMENT OF FISHERS IMPACT FEE REVIEW BOARD.** In accordance with IC 36-7-4-1338, three citizen members who serve without compensation: a real estate broker licensed in the state, an engineer licensed in the state, and a certified public accountant. Duties and responsibilities include reviewing the amount of an impact fee assessed, the amount of a refund, and the amount of a credit.

§ **156.51 COMPLIANCE WITH HOUSE ENROLLED ACT NO. 1467.** Acknowledges IC 36-7-4-1300 et seq, which regulates the imposition of impact fee ordinances by municipal corporations within the state.

§ **156.52 AMENDMENTS AND REVIEW**. Annual review to be made by town staff or consultants to determine the continuing validity of the Impact Fee, the Impact Zone, and the Zone Improvement Plan.

Because the Fishers ordinance closely follows the provisions of the Indiana Code, it can serve as a good starting point for a traffic impact fee ordinance. Of course, conditions specific to a particular local unit of government may make some adjustments necessary.

6. INNOVATIVE INTERSECTION DESIGNS

As vehicle usage on the nation's road network continues to increase, users experience increased congestion and delay. Conventional intersection designs at times are not able to accommodate increases in traffic flows (*23*). Innovative designs may be able to improve the operation of the intersections. An "innovative intersection" is one that incorporates geometric design features that cause it to function significantly differently from a traditional stop-controlled or signalized intersection. Examples of innovative intersection designs will follow in the coming sections.

A traffic impact analysis analyzes the impact of additional traffic from a new development on the surrounding existing road network. Part of the analysis includes assessing the impact of the new traffic on the level of service on the existing road network and determining what improvements are needed to facilitate the new traffic volumes. Intersections are of particular interest. With the addition of the site-generated traffic, one or more nearby intersections may no longer operate at an acceptable level-of-service. A conventional intersection may not be the best way to handle the increased flow of vehicles at the intersection. Some innovative designs may offer a better solution.

6.1 Multi-Modal Intersections

Planning and designing for transportation modes other than motor vehicle is one approach engineers and planners can use to improve traffic operations. Engineers, especially in urban areas, are putting more emphasis on understanding how different modes of transportation interact with each other and evaluating the level-of-service provided by each mode. Chapters 16: Urban Street Facilities and Chapter 17: Urban Street Segments of the *Highway Capacity Manual* (*6*) contain methods to evaluate level-of-service for vehicles, transit, pedestrians and bicyclists. Chapter 16 contains methodologies to analyze the level-of-service for the four previously mentioned modes of transportation for specific urban facilities, such as an urban intersection or one block of an urban street. Chapter 17 provides analysis methodologies for the same modes of transportation, but applies them to an urban segment. This segment could be an urban corridor that would include both intersections and the road segments in between the intersections, as an example.

Some engineers and planners are also implementing context sensitive solutions (CSS).

- CSS provides urban streets that support multiple functions and are walkable.
- CSS seeks to bring back the mixing of economic and social functions along arterials and collectors (*24*).
- CSS incorporates some of the principles of new urbanism/neotraditionalism as well as the smart growth movement (*25*).
- CSS is geared to increase pedestrian and bicycle traffic as well as mass transit use, which meshes well with new standards set forth in the *Highway Capacity Manual* (*6*) to evaluate how all modes of transportation operate.

Implementing these types of facilities may reduce vehicular traffic on the surrounding road network, reducing the impact of new developments on the road network.

6.2 Innovative Intersection Geometry

New geometric designs for intersections have been implemented across the U.S. Many of the new designs are intended to reduce crash severity and frequency. They may also improve traffic operations by reducing delay. The modern roundabout is the most common innovative intersection design in the United States. More information regarding roundabouts is given in the chapter about roundabouts. The restricted-crossing U-turn (RCUT), median U-turn (MUT), displaced left-turn (DLT), and quadrant roadway (QR) intersections are other relatively new intersection designs. A brief summary and illustration of each of these intersection designs is provided in the next four sections.

6.2.1 Median U-Turn Intersections

A modification of the conventional intersection design is the median U-turn (MUT). This type of intersection is also known to some as the median U-turn intersection treatment (MUTIT) or the Michigan left-turn (*26*). A full MUT prohibits all left turns at the signalized intersection. Left turns from the major street must be conducted by going past the intersection, using the median U-turn, and then making a right turn onto the minor street. Left turns from the minor street are conducted by making a right turn onto the major street, then using the median U-turn to turn around and head the desired direction (*23*). A visualization of how a left turn would be performed at a MUT can be seen in Figure 6.1. Based on what was found in literature, MUTs are signalized intersections (*23*). It is possible that the main intersection could be unsignalized, if the minor street has very low traffic volumes. The elimination of left-turn phases of the signal cycle allows for shorter cycle lengths and shorter delays at the intersection.

In recent years, the MUT has been successfully implemented in Florida, Louisiana, Maryland and New Jersey (*26*). They have been used extensively in

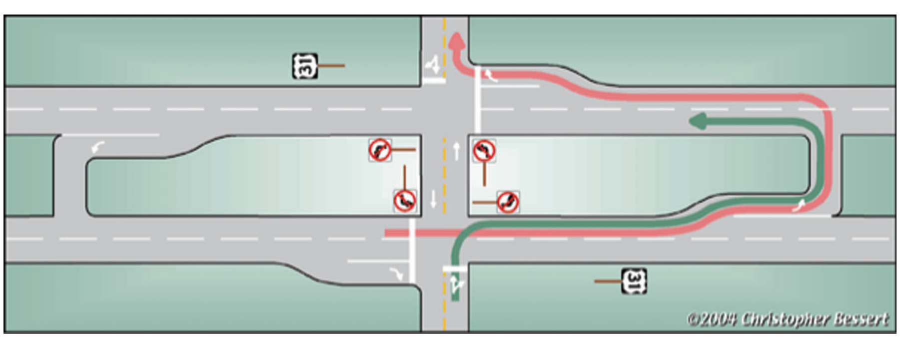


Figure 6.1 Left turn movements at an MUT (*26*).

Michigan since the 1960s, when the MUT was first developed. The Michigan Department of Transportation currently has over 700 MUTs on its highway system (*23*). Aerial views of two MUTs in Troy, Michigan, may be seen in Figure 6.2 and Figure 6.3.

A number of possible variations on the MUT exist. One variation, the restricted-crossing U-turn, is presented later in this chapter. Other variations may be found in the chapter on the MUT in the Federal Highway Administration's informational report "Alternative Intersections/Interchanges" (*23*). According to Jagannathan (*26*), the advantages of MUTs are:

- "Reduced delay and better progression for through traffic on the major arterial.
- Increased capacity at the main intersection.
- Fewer stops for through traffic, especially where there are STOP-controlled directional crossovers.
- Reduced risk to crossing pedestrians.
- Fewer and more separated conflict points.
- Two-phase signal control allows shorter cycle lengths, thereby permitting more flexibility in traffic signal progression."

Hummer and Reid (*29*) list the disadvantages of MUTs as:

- "Driver confusion,
- Driver disregard of the left turn prohibition at the main intersection,
- Increased delay for left-turning traffic,
- Increased travel distances for left-turning traffic,
- Increased stops for left-turning traffic,
- Larger rights-of-way along the arterial"

Signal costs may also increase if the median crossovers are signalized, because this would require more signals to be installed, operated and maintained.

The town of Fishers, Indiana, is currently in the process of reconstructing an existing intersection as a MUT. The intersection of 96th Street and Allisonville Road is being converted to a MUT to reduce wait times at the intersection, as well as to minimize impacts to the surrounding developments and reduce construction cost (*30*). This location could be monitored to analyze how the MUT works and determine if other locations could benefit from this type of intersection, including expansion to other intersections along the 96th Street corridor.

6.2.2 Restricted-Crossing U-Turn Intersections

A variation of the MUT that has its own name is the restricted-crossing U-turn intersection or RCUT. RCUT intersections "have the potential to move more vehicles efficiently and safely than… conventional at-grade intersections with minimal disruptions to adjacent development" (*22*). An RCUT intersection restricts some movements from the minor street approaches to an intersection with a divided major road. All RCUT intersections redirect vehicles approaching on the minor street wishing to conduct a through or left-turn movement to instead make a right turn onto the major road. A short distance along the major road, these vehicles are able to cross over via a U-turn in the median, and would then continue along the major road as desired or make a right-turn onto the minor street approach opposite of the approach on which they entered (*31*).

The RCUT is also known as a super street intersection. RCUTs are regulated by traffic signals located at the main intersection and occasionally at the U-turns upstream and downstream from the intersection. An overhead view of an RCUT may be seen in Figure 6.4. The lanes have clear markings as to what movement is to be performed, aiding drivers in properly navigate the intersection. A center diagonal island separates the two major-street left turn movements, and other channelization islands often accompany the turn movements to guide drivers. A variation of the RCUT, which has been termed in Maryland as the "J-turn," does not have signalization at the intersection or at the

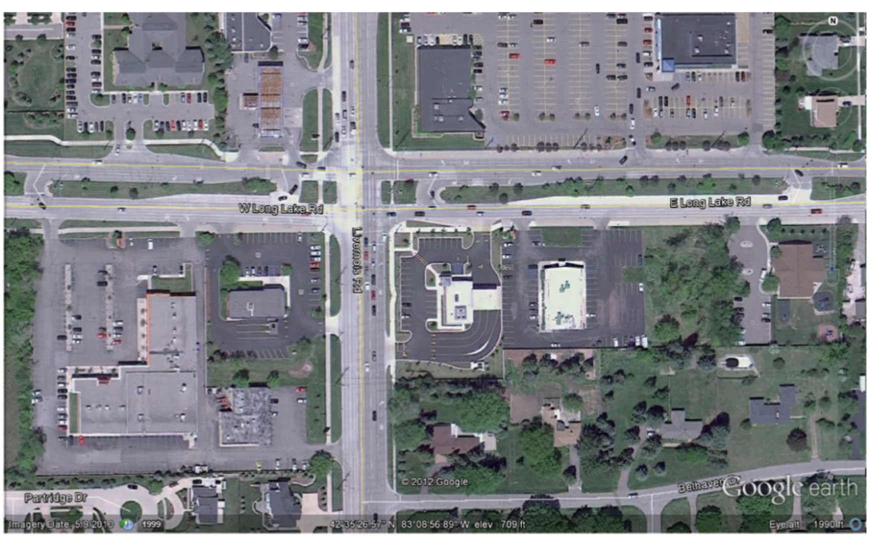


Figure 6.2 MUT intersection in Troy, MI (*27*).

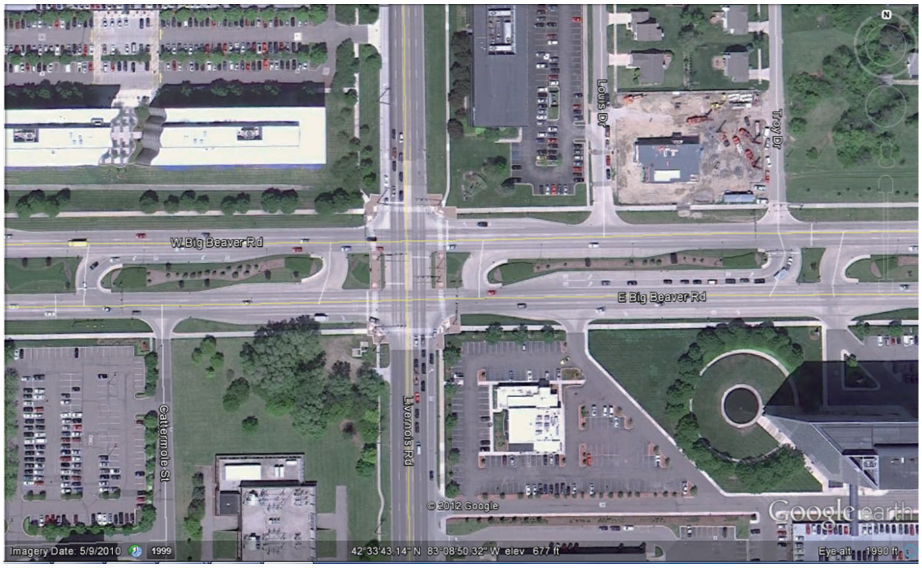


Figure 6.3 MUT in Troy, MI with two U-turn lanes at the eastbound crossover (*28*).

crossover U-turns (*23*). An aerial view of a J-turn may be seen in Figure 6.5. All further mentions of RCUTs in this report will include J-turns unless specifically stated otherwise. Both geometric configurations have a crossover U-turn on each side of the intersection, but the crossover U-turns are not visible in the figures.

RCUT intersections are able to provide some operational and safety improvements over conventional intersections. RCUTs are usually implemented as part of a treatment along a corridor, but they may also be implemented at isolated intersections (*31*). A major advantage of RCUTs is a reduction in crash severity. RCUTs have fewer conflict points compared to a conventional intersection, and the crashes that occur are expected to be less severe (*23*).

Figure 6.4 RCUT intersection, US 53 at County Road B, Douglas County, WI (*32*).

The geometry of an RCUT intersection may not be as pedestrian-friendly as a conventional intersection, depending upon the version of the RCUT. Some versions require longer pedestrian paths than others. Especially for visually impaired pedestrians, the route needed to cross the street may not be intuitive (*23*). Special RCUT geometric configurations may be needed to accommodate pedestrian traffic when in a suburban setting, but RCUT intersections are more effective in low-pedestrian volume situations.

The RCUT is not always a more effective solution than a conventional intersection. RCUTs are only able to be implemented on median-separated roads, many of which are major arterials. Inman and Haas (*33*) recommend they be considered for minor road intersections with four-lane divided highways where there are sufficient volumes on the minor road. No specific volume levels for the minor road were presented in the report. Hummer et al. (*34*) conducted traffic counts while analyzing RCUT intersections in North Carolina. The peak hour counts for each minor street approach are presented in Table 6.1. Each major street approach had a peak hour count of between 1000–2000 vehicles per hour (vph).

RCUTs have been implemented in both rural and suburban settings (*23*). The best locations for applying an RCUT include:

- "Relatively low to medium side-street through volumes and heavy left-turn volumes from the major road.
- The minor road total volume to total intersection volume ratio is typically less than or equal to 0.20.
- Areas where median widths are greater than 40 ft. For narrower medians, loons on the shoulders need to be constructed" (*31*).

When heavy left-turn and through volumes exist on the side street approaches, the RCUT intersection design becomes less efficient than a conventional intersection (*23*). Large trucks require greater right-of-

Figure 6.5 J-turn intersection at US 64 & Mark's Creek Road in North Carolina (*28*).

way widths to conduct a U-turn. The wider median needed for U-turn space for large trucks is disadvantageous because the greater right-of-way needed increases the cost of construction. A loon (Figure 6.6) may be constructed for narrower medians instead of increasing the median width to provide a larger turning radius for trucks. A loon is an extension of pavement for a short distance that bulges out to provide a wider area to conduct a U-turn.

Both RCUTs and MUTs may be used as part of an access management tool for a corridor, if the governing jurisdiction wishes to limit access to the major road. Both types of intersections require some form of median in order for vehicles to conduct U-turns. Driveways with median breaks near the main intersection or the median crossovers can negatively impact the progression of traffic along the corridor. Locating a driveway at a median crossing (as long as no loon is present on the opposite side) so that it may serve left turns into or out of the driveway may increase the efficiency of the corridor (*23*). The operational performance of the major road should be a major factor when determining an access break.

6.2.3 Displaced Left Turn Intersections

The displaced left-turn moves left turn lanes laterally across the oncoming lanes of through traffic before the main intersection. "DLT intersections are also referred to as continuous flow intersections (CFI) and crossover displaced left-turn intersections (XDL)" (*23*). The crossovers are signalized, as is the main intersection. Left turning traffic crosses over a few hundred feet before the main intersection. The intersection may be built as a partial DLT, as seen in Figure 6.7, or a full DLT, as Figure 6.8 shows in the conceptual drawing.

For a partial DLT, the left turns on either the major or minor road may be the ones displaced. The signals at all of the crossovers and the main intersection are timed so that a vehicle on any approach will at most have to wait through one red phase (*35*). When looking for alternatives when a conventional intersection is no longer adequate, a DLT could be an at-grade intersection option instead of a grade-separated intersection or additional through lanes to increase capacity.

DLTs have been implemented in few locations around the country. Jagannathan et al. (*35*) noted 5 locations: Baton Rouge, LA; St. Louis, MO; Long Island, NY; Accokeek, MD; and Salt Lake City, UT. They also mentioned a few other locations that were considering them.

A DLT has a few advantages. Depending on the cost of right-of-way and location, it may be less expensive than a grade-separated intersection. DLTs offer fewer conflict points than a conventional intersection and also improve platoon progression by allowing left-

TABLE 6.1
RCUT minor street approach traffic volumes (*34*)

Intersection	Peak hour traffic volumes (vph)	
	WB	**EB**
US 421 at Myrtle Gardens Dr./Carolina Beach Rd. in Wilmington, NC	236	145
US 17 at Ploof Rd./Poole Rd. in Leland, NC	49	468
US 17 at Walmart/Gregory Rd. in Leland, NC	422	47
US 17 at Grandiflora Dr./West Gate Dr. in Leland, NC	472	471
US 17 at Brunswick Forest Pkwy. in Leland, NC	457	N/A
US 17 at Lanvale Rd./Brunswick Forest Dr. in Leland, NC	423	49

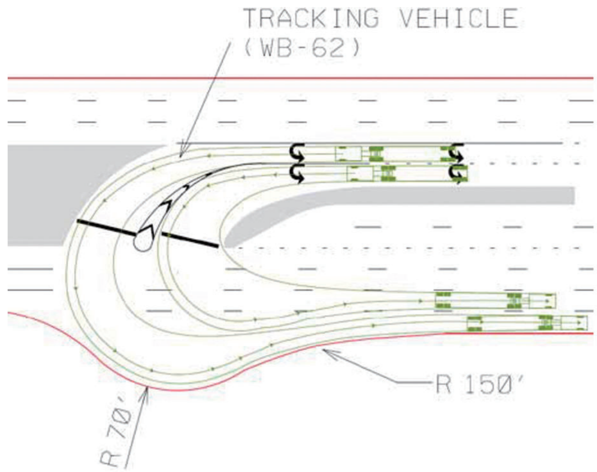


Figure 6.6 Example of a loon at a median crossover (*23*).

turning and through traffic to move through the intersection simultaneously (*23*). The need for right-of-way is the major disadvantage of a DLT. A DLT would most likely not be a good fit for an urban area with limited right-of-way. Because DLTs are not widely used, driver unfamiliarity with how to navigate the intersection would be another disadvantage. The geometry of a DLT also limits access to adjacent developments and can cause confusion for pedestrians (*23*). Jagannathan et al. (*35*) recommend considering a DLT for the following situations:

- "If the volume/capacity ratio is greater than 0.8 on two opposing intersection approaches.
- If the product of left-turn and opposing through vehicles is greater than 150,000 on two opposing intersection approaches.
- If the left-turning volume is greater than 250 vehicles per lane and the opposing through volume is greater than 500 vehicles per lane during peak hours on two opposing intersection approaches.
- If an intersection is heavily congested with many failures of signal phases to handle peak traffic volumes."

6.2.4 Quadrant Roadway Intersections

An intersection design alternative not requiring the major street to have a median is the quadrant roadway (QR). At this time, no known full QR intersections have been constructed in the United States. Some engineers believe the QR to be a promising intersection design alternative where two major roads meet in either suburban or urban areas, however (*23*). A QR moves all left turns from the main intersection to a connector roadway in one quadrant of the intersection. Diagrams of the left-turning movements for a QR can be found in Figure 6.9.

According to Hughes et al. (*23*), QR intersections can be efficient with many traffic demand levels, but they are especially efficient when there is a large volume of through traffic and low to moderate left-turn volumes. Improved progression can be achieved by coordinating the secondary signalized intersections (intersections with the quadrant road) with the main signalized intersection. A view of a partial QR in Broomfield Hills, Michigan may be seen in Figure 6.10.

6.2.5 Roundabouts

Modern roundabout (hereafter stated as roundabout) intersections are becoming more prevalent across the United States. Roundabouts are characterized by splitter islands and flared entrances to the circulating lanes. Generally, roundabouts are constructed to safety and/or operational characteristics of the intersection. Operational improvements could include reduction in travel time, user delay and/or vehicle emissions. As vehicle speed increases within a roundabout, entering traffic requires larger gaps to comfortably enter, and fewer comfortably acceptable

Figure 6.7 Partial DLT at Missouri Route 30 and Gravois Bluffs Blvd. in St. Louis, MO (*27*).

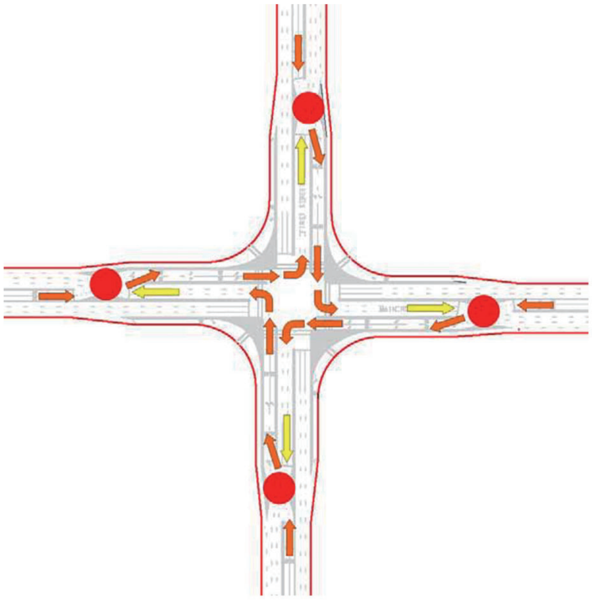


Figure 6.8 Full displaced left-turn intersection (*23*).

gaps are present. By forcing traffic to slow down, the gap size drivers will accept shrinks, increasing the number of acceptable gaps and capacity at the roundabout (*36*). More continuous flow at the intersection would decrease the amount of capacity needed on the legs of the roundabout, allowing the implementation of road diets (*37*). The most recent edition of the *Highway Capacity Manual* (*6*) devotes an entire chapter to the design of roundabouts with one or two circulatory lanes. The interactions and relationships between vehicles and drivers, along with driver perceptions, in the United States have not been well studied; therefore, current design thresholds are the same as those for unsignalized intersections.

The first modern roundabout (as opposed to traffic circles and rotaries) in the United States was built sometime during the 1990s (*38*). Because roundabouts are relatively new to the United States, many drivers are unfamiliar with them and, therefore, uncomfortable and hesitant when driving on them (*6*). The performance of roundabouts may improve as drivers become more familiar and comfortable with them. This will happen through drivers being willing to accept smaller gaps in traffic and familiarity with how to navigate roundabouts. Analysis and design tools will also improve as more studies are conducted on roundabout operations.

Roundabouts are already present in some locations in Indiana and more are planned. The first roundabout on a road under INDOT's jurisdiction was constructed in Valparaiso on Indiana State Route 130 (*39*). Figure 6.11 provides an aerial view of the roundabout in Valparaiso. Many other roundabouts have been constructed in the state of Indiana. Carmel, just north of Indianapolis, has built more than 70 roundabouts within the community (*39*). Carmel has also constructed roundabouts at interchanges along Keystone Parkway, as it is now called. When Carmel took over control of what was then known as Keystone Avenue, the city decided to convert it to a limited access highway and install roundabouts at six interchanges along it, in preparation for construction that would be done in subsequent years to upgrade US 31 (*40*). The success of the interchanges with roundabouts along Keystone Parkway has led to INDOT planning to construct two similar interchanges along US 31 in Carmel, with the possibility of more in the future (*39*). The next few years could provide more information on how well roundabouts work on roads managed by INDOT.

With the increasing presence of roundabouts across Indiana, it is clear they are being considered as possible design options for intersections. Roundabouts should be included in the traffic impact analysis manual in order to ensure their proper usage. Reviewers will want to know what is the best intersection alternative (in

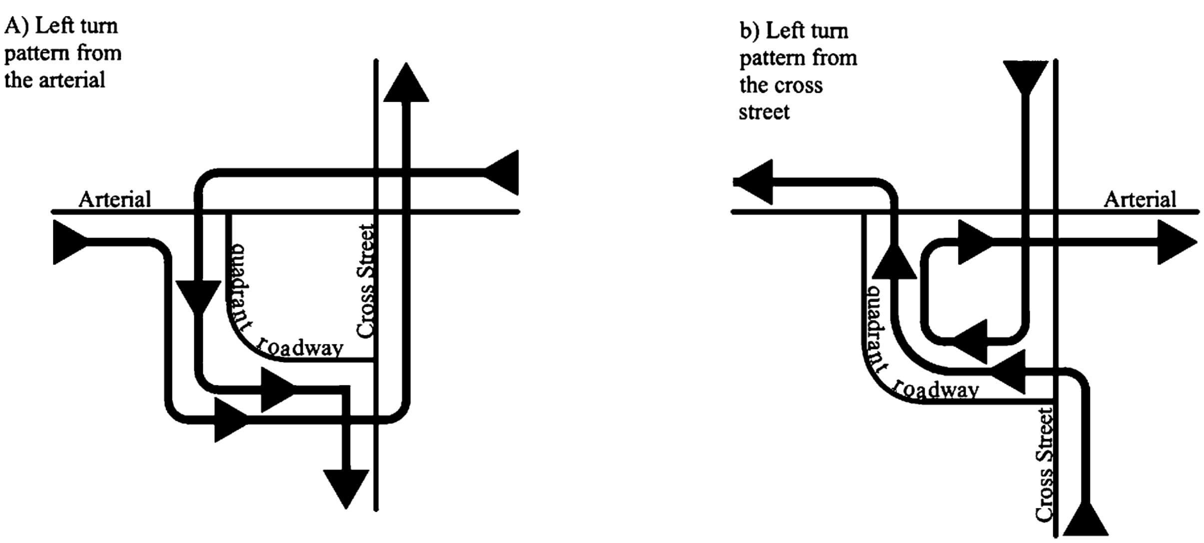


Figure 6.9 QR left turn movements (*23*).

Figure 6.10 Partial QR at Telegraph Rd. & W. Maple Rd. in Broomfield Hills, MI (*28*).

terms of performance) in each situation, which may be a roundabout. For developers, it provides them with another potentially less expensive intersection alternative. Inclusion in the traffic impact analysis manual would ensure proper thresholds for roundabouts are met. Including roundabouts in TIA would be especially useful currently, as many people are still unfamiliar with roundabouts.

6.3 Public Response

Opposition often accompanies the decision to implement an intersection design unfamiliar to the local public. Most of the opposition is due to locals being unfamiliar with how these intersections are meant to operate and how they should navigate the intersections. Holding an information session to provide the public with training on how to operate the intersection and explaining why that type of intersection is being implemented can gain public support for the project and also increase safety by having better informed drivers using the intersection. INDOT has used this approach to inform the public on how to navigate roundabouts safely, most recently for the roundabout on State Road 25 north of Lafayette (*41*). It is recommended that if any alternative intersection designs are implemented that an information session be presented to the public to explain the benefits of the intersection and how to navigate the intersection. Additional or more prominent signage and/or pavement markings near the intersections may also aid in helping drivers navigate the intersection properly.

Figure 6.11 Roundabout on SR 130 in Valparaiso (*28*).

7. SIMULATION ANALYSIS OF INNOVATIVE INTERSECTION DESIGN

7.1 Introduction

While Chapter 6 provides an introduction to a few innovative intersection designs and how those intersections function, it does not prove that in certain situations they may operate more effectively than conventional intersections. If the innovative intersection does not operate as hoped, large sums of money may be wasted. With the introduction of microsimulation software, traffic engineers can run simulations to predict how a new intersection design may operate.

While simulation packages have been developed with parameters (such as those set forth in the *Highway Capacity Manual*) to analyze conventional intersection geometries, those parameters may not provide the most accurate analysis of intersections that incorporate innovative design features. For example, in order to better analyze roundabout operations, the most recent edition of the *Highway Capacity Manual* (*6*) devotes an entire chapter to methodology to compute level-of-service. This is not to say each innovative design requires a new methodology, but some innovative designs may require some modifications in order for the analysis to be useful. For this reason, a several of the innovative designs previously discussed were compared against conventional stop-control and signalized intersections.

7.2 Methodology

TransModeler was the software package used for the analyses in this research (*42*). An example scenario was created in which to compare the performance of some innovative intersection designs with conventional designs. Rather than using a specific location within Indiana, the purpose was to analyze a geometry that INDOT would typically encounter and that could also be encountered by other jurisdictions. Each intersection's geometry was drawn over an aerial image of a divided highway intersected by a two-lane road. This was done to more accurately represent each intersection's geometry. The basic intersection design was a four-lane divided state highway intersecting a two-lane rural highway not under INDOT's jurisdiction. This intersection configuration was chosen because it is likely to have traffic volumes that vary by approach direction.

In order to conduct an analysis of the various intersection designs, a number of assumptions had to be made. A certain percentage of the traffic volume from each approach was assumed to make left, right and through movements. The assumed percentages for each movement per approach can be seen in Figure 7.1. The movement percentages were selected by assuming a majority of the major highway traffic would be through traffic and that larger percentages of traffic on the minor highway would be headed towards traffic generators on either end of the major highway, as opposed to conducting a through movement across the major highway. The volume for the major highway (controlled by INDOT) was kept constant throughout the simulations. The volume on the minor highway was varied from a balanced condition to very unbalanced flows. Table 7.1 lists the volumes used per approach for each simulation.

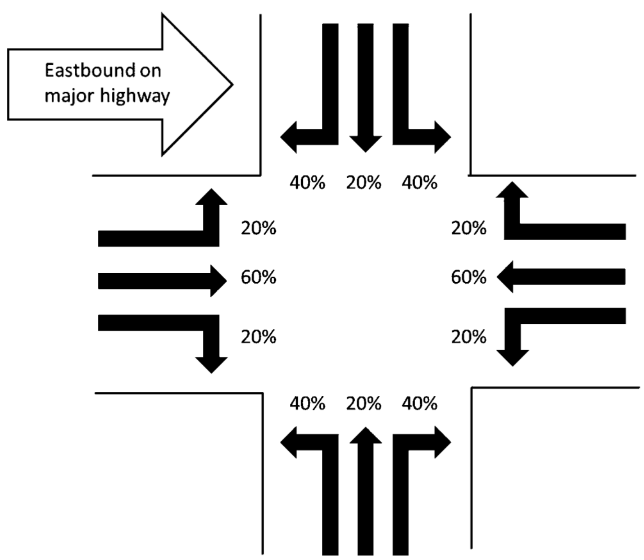


Figure 7.1 Assumed percentage of directional volume by movement.

In addition, the number of lanes per approach for each intersection design was kept the same throughout the numerous simulations. This was necessary because any changes to each intersection's geometry could affect traffic operations and possibly alter the amount of delay vehicles experience. Figure 7.2 shows the geometry of each intersection. Figure 7.2 also shows the assumed speeds for each intersection approach based upon what seemed common for similar highways in Indiana. It should be noted that for the median U-turn (MUT) intersection, a single lane crossover with a deceleration lane before entering the crossover and an acceleration lane after leaving the crossover was provided on either side of the main intersection on the major highway to facilitate left turn movements. The crossovers are not shown in the geometry of Figure 7.2, but one of the median crossovers from the simulation model is visible in Figure 7.3. All turn lanes were 250–300′ in length and the inside diameter of the roundabout was 140′. A ninety-second cycle length was used for all signals to attempt to maintain consistency between signal timings for the conventional signalized intersection and the MUT.

For each simulation run, a single hour representing the peak hour was analyzed. *Delay* was selected to be used as a performance measure to compare the performance of the different intersections. TransModeler measures delay in three ways: by link, by node and by lane. The delay by lane was selected because it provides a better perspective of how each type of movement at an intersection is impacted by changing geometry and traffic flows. On some approaches, one lane served two movements and, therefore, the delay is representative for both movements. In TransModeler, delay is defined as, "the difference between experienced travel time and that travel time that would be realized in the absence of other vehicles, traffic controls, or other factors impeding traffic flow" (*43*). The delay for each movement will be compared to determine which geometries are more effective for different traffic volumes.

For the MUT and roundabout, the added travel time incurred by being forced to proceed past the main

TABLE 7.1
Approach volumes (each direction) used in the intersection simulations

Simulation	Volume (vph) Major hwy	Volume (vph) Minor hwy
1	800	800
2	800	700
3	800	600
4	800	500
5	800	400
6	800	300
7	800	200
8	800	100

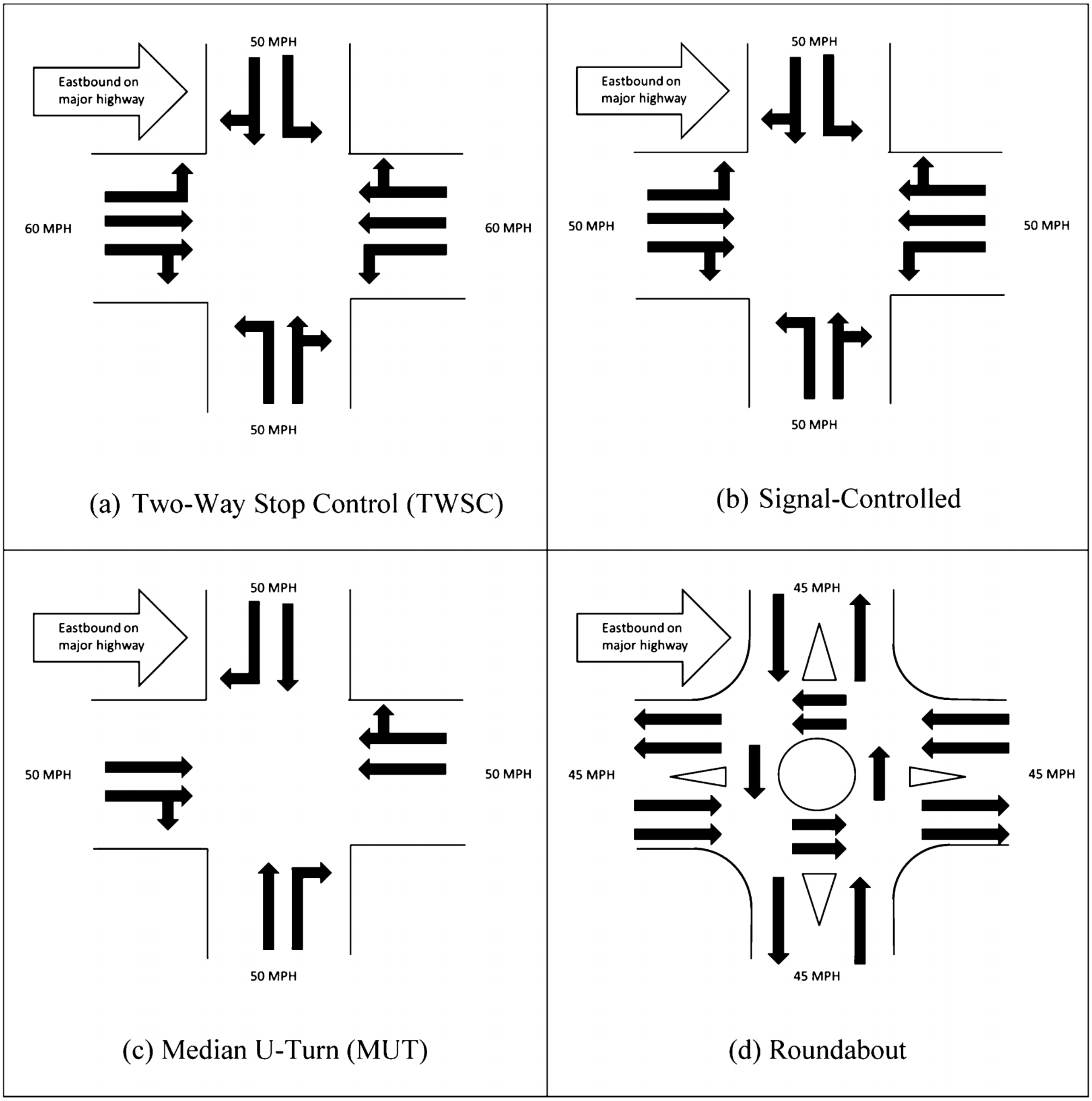


Figure 7.2 Simulation intersection configurations.

intersection and utilize a median crossover (for the MUT) or circle around the central island to exit onto the desired street (for the roundabout) does not appear to be accounted for in the calculated delay. Because TransModeler calculates delay as the difference between the experienced travel time and the travel time without impeding factors, the time taken to travel further through the intersection would cancel out, preventing this time from being included in the comparison between intersections. As would be expected, this would add a few seconds of time to the total delay if it were to be included to more directly compare them to a conventional intersection. For a roundabout, it may add around five seconds at most, depending upon the roundabout configuration and current traffic volumes. The delay at an MUT is more variable than at a roundabout. When a MUT's crossovers are located further downstream, more time would be required to conduct the U-turn and would increase the amount of delay.

7.3 Results

After each simulation run, a report was generated by TransModeler that showed the calculated the average delay per vehicle per lane and also the summed total delay experienced by all vehicles traveling along each

Figure 7.3 MUT median crossover from the simulation model.

lane. The average delay per vehicle per lane was copied into a table to compile the data from all of the simulation runs. Having all of the data in one table made it easier to spot trends in the data and to make comparisons between the different intersections. The simulation results may be found in Figure 7.4 and Figure 7.5.

As the volumes on the minor highway approaches decreased, the average delay experienced by vehicles generally decreased for each intersection. Less delay will be encountered by other vehicles approaching the intersection when there are fewer vehicles with which to conflict. During the first several simulations, where the flows on the minor and major highways were more balanced, the MUT caused significantly less delay for the intersection as a whole. The minor street approaches operated much more efficiently at the MUT than at the other intersection types. Delays on the major street were higher than the others, but taken as a whole the MUT operated more efficiently. From simulation 3 through simulation 8, the roundabout clearly stood out as having lower delays. The disadvantage with the roundabout, however, is that all vehicles are forced to slow down to navigate the intersection, whereas vehicles may reach the intersection at the correct time to continue unimpeded at the MUT or signalized intersections. The two-way stop-control intersection caused the lowest average delays for all simulations on the major highway (Figure 7.5), but when combined with the high levels of delay experienced on the minor highway (Figure 7.4), may not prove to be the best solution.

The results aren't entirely as would be expected, though. The average delay at times increases on some approaches increased as the minor highway volume was decreased from the previous simulation. Some of this may be attributed to the stochastic nature of the simulation. Because the volume of the major highway does not change, there would not be more acceptable gaps for minor highway traffic, which may explain why the average delay does not change much between some simulations. It is not clear if this is entirely explains the somewhat volatile results from TransModeler. Adjusting some of TransModeler's settings (i.e., the gap acceptance parameter) may produce results that are less volatile.

A very interesting result occurred in simulation 3 on the minor highway approaches. Compared to simulation 2, the delay experienced by the northbound and southbound approaches of the roundabout drastically decreased. The simulation was repeated a couple times and similar results were observed. It is not clear whether the reduced traffic volumes on the north and southbound approaches in simulation 3 were low enough to allow vehicles to discharge quickly enough to prevent a long queue from forming or if some other factor caused such a dramatic reduction in delay. After the significant decrease between simulations 2 and 3, though, the delay decreased slowly and steadily through the rest of the roundabout simulations.

TransModeler produced another interesting result. It was expected that the through movement on the major highway in a two-way stop-controlled (TWSC) intersection would not experience any delay. The results output by TransModeler, however, observed between one and two seconds average delay for vehicles making this movement through the TWSC intersection. A possible explanation for this may be that vehicles in the outer (driving) lanes on the major road were forced to slow down for vehicles conducting a right turn in front of them.

It is not possible to say from this analysis that one intersection design is better than the others for a given situation, however. There are other modifications that could have been made to the intersections that may or may not have improved operations. Changes to geometry or signal settings could possibly have improved each of the different intersection configurations. Signal cycle lengths could have been changed, signal splits could be adjusted and additional turn or through lanes could have been added, among other modifications that could improve performance. The median crossovers for the MUT were not signalized in the simulations, but the option to signalize them would

Simulation	Intersection Type	Control Delay By Movement Per Approach (s/veh)					
		Northbound			Southbound		
		Left	Through	Right	Left	Through	Right
1	TWSC	156.2	144.9		144.0	130.4	
	Traffic Signal	126.9	126.1		127.9	127.2	
	MUT	52.7	29.1	31.3	56.5	34.0	34.9
	Roundabout	114.3	110.6	103.5	140.8	137.1	130.0
2	TWSC	141.8	138.3		139.0	134.5	
	Traffic Signal	115.0	109.1		127.0	119.3	
	MUT	49.1	32.6	27.5	48.2	33.8	26.6
	Roundabout	108.3	104.5	97.4	120.2	116.4	109.3
3	TWSC	150.0	110.2		138.8	142.7	
	Traffic Signal	105.1	114.4		92.3	79.8	
	MUT	42.5	31.5	21.1	43.2	32.3	22.0
	Roundabout	26.6	22.9	15.9	26.7	23.4	16.3
4	TWSC	137.1	137.5		126.4	148.8	
	Traffic Signal	36.1	32.9		47.9	44.3	
	MUT	38.1	33.6	16.6	39.7	31.8	18.4
	Roundabout	21.6	17.9	10.9	20.2	16.6	9.5
5	TWSC	143.6	142.1		152.5	143.4	
	Traffic Signal	28.7	27.3		34.6	28.4	
	MUT	34.7	29.6	13.7	35.1	28.6	14.2
	Roundabout	19.5	15.9	8.8	18.8	15.5	8.5
6	TWSC	142.9	122.7		135.1	143.2	
	Traffic Signal	31.2	23.5		32.2	27.0	
	MUT	31.9	29.3	11.0	34.1	31.4	13.2
	Roundabout	19.1	15.5	8.5	18.4	14.8	7.9
7	TWSC	118.1	131.6		116.2	140.5	
	Traffic Signal	26.5	19.1		31.4	18.5	
	MUT	32.1	32.9	10.9	32.0	29.4	11.3
	Roundabout	18.2	14.7	7.7	18.1	14.6	7.7
8	TWSC	51.4	101.9		41.8	95.7	
	Traffic Signal	32.3	20.5		31.7	16.7	
	MUT	30.5	31.0	9.6	31.3	28.8	10.8
	Roundabout	18.0	14.5	7.6	17.3	14.0	7.2

Figure 7.4 TransModeler intersection simulation results for the minor highway approaches.

Simulation	Intersection Type	Control Delay By Movement Per Approach (s/veh)					
		Westbound			Eastbound		
		Left	Through	Right	Left	Through	Right
1	TWSC	8.3	1.7		6.1	1.7	
	Traffic Signal	23.1	19.2		22.7	20.7	
	MUT	37.7	16.1		37.8	16.4	
	Roundabout	19.9	16.1	9.0	20.2	16.4	9.3
2	TWSC	11.4	2.0		9.1	1.8	
	Traffic Signal	23.2	20.5		26.6	20.4	
	MUT	33.8	12.2		34.4	12.8	
	Roundabout	20.0	16.2	9.1	20.2	16.4	9.3
3	TWSC	9.4	1.8		7.5	1.7	
	Traffic Signal	44.0	21.4		38.1	19.9	
	MUT	31.7	10.5		31.8	10.4	
	Roundabout	19.6	15.9	8.8	19.9	16.2	9.2
4	TWSC	9.7	1.9		7.7	1.9	
	Traffic Signal	46.2	19.5		47.4	19.0	
	MUT	31.4	10.1		31.0	9.6	
	Roundabout	19.6	15.9	8.9	19.4	15.7	8.8
5	TWSC	8.0	2.0		7.4	1.7	
	Traffic Signal	23.8	16.9		37.1	17.0	
	MUT	30.6	9.7		30.1	9.1	
	Roundabout	19.5	15.8	8.8	19.5	15.8	8.8
6	TWSC	8.8	2.1		6.8	1.9	
	Traffic Signal	22.9	14.7		34.7	14.5	
	MUT	29.8	9.0		29.1	8.2	
	Roundabout	19.3	15.6	8.7	19.2	15.5	8.6
7	TWSC	8.4	2.1		7.2	1.9	
	Traffic Signal	29.6	12.0		24.5	12.9	
	MUT	28.7	8.1		33.8	8.1	
	Roundabout	22.4	15.6	8.7	19.1	15.3	8.5
8	TWSC	6.4	2.1		7.1	1.9	
	Traffic Signal	20.4	9.2		18.1	9.5	
	MUT	28.1	7.6		28.4	7.5	
	Roundabout	18.8	15.1	8.4	18.9	15.3	8.4

Figure 7.5 TransModeler intersection simulation results for the major highway approaches.

be available when determining the best configuration for an intersection. The location of the crossovers would also make a significant difference. The further downstream from the main intersection the crossovers are located, the longer it will take drivers to make a left turn.

Different assumptions prior to analysis could have a significant impact as well. Adjusting the proportion of trips making left, through and right turn movements on each approach could significantly change the results of the analysis. Local conditions, both current and future, for each project would be an important factor in determining the best intersection design to implement. An engineer performing an actual study of an intersection would need to adjust some of the parameters assumed in the analysis in order to determine the optimal solution for each project.

8. DEVELOPMENTS THAT AFFECT ROADS IN MULTIPLE JURISDICTIONS

INDOT is the governing jurisdiction for all state and federal highways in the State of Indiana. All other public roads in the State of Indiana are governed by local governments—at the city, town, or county level. Developments are guaranteed access to public roads, but the access points may not lie directly along state-controlled roads. The site access may occur along a local road, at one or more locations close enough to a state road to affect the operation of the state road. In such circumstances, the decisions of a local jurisdiction can determine the quality of access to the site and the level of service at the nearby intersection with the state road.

When a property owner or developer seeks access to a state highway, an application for an access permit must be sent to the Permits Office of the governing INDOT District. IC 9-21-19-1, has the heading "Permit requirements":

> Sec. 1. A person may not: (1) construct a private entrance, driveway, or approach connecting with a highway in the state highway system or the state maintained route through a city or town; or (2) cut or remove a curb along a highway; without a written permit from the Indiana department of transportation. The action must be in accordance with the rules and requirements of the department.

Unfortunately, property owners who do not require state highway access are not required to inform INDOT of the proposed development.

8.1 A Basic Example

Figure 8.1 illustrates a basic example of a development that could affect multiple jurisdictions.

A number of variables factor into the impact a development could have on a nearby intersection with a state highway. The type, size and density of land use at the development site, distance to the intersection with the state highway, amount of background traffic, location (suburban versus rural), and the number of alternate routes other than the state highway may all affect a development's potential impact on the intersection. With so many variables affecting the intersection with the state highway system, each development must be analyzed separately to determine its impact. Jurisdictions should work together to determine a development's impact on the surrounding communities. In such cases, "Although much of the traffic associated with the development may use the State highway, INDOT is limited in its ability to require mitigating measures to compensate for this additional traffic" (*7*). Increasing communication in these situations could greatly benefit both INDOT and the local government entities. It could also ensure safer and more efficient access to the site.

If INDOT were informed of a development that could significantly affect an intersection or segment of highway under its jurisdiction, but is not informed until late in the development process, the project may gain approval from the local government entity before INDOT is able to assess predicted impacts on its network from the development. As stated in the *Access Management Guide* (*7*), "Simply involving INDOT or the local road agency early in the process of planning and reviewing a development can produce many benefits, because access-related issues can be raised earlier and solutions more easily identified." If possible, all affected parties should be present at the scoping meeting, because this occurs early enough in the development process to allow each side's concerns and desires to be made known allowing remedies that are more convenient and economical.

8.2 How to Encourage Coordination between Jurisdictions

While it is clear that coordination between jurisdictions is desirable, the challenge is to have the right persons in LPAs remember to contact other jurisdictions and agencies that may be affected by a proposed development. As this project proceeded, several complementary strategies emerged.

1. Make the INDOT TIA Guides applicable to LPA cases. Good practices for TIA are the same for city, town, county, and state jurisdictions. To the extent that the guides produced by this project are used by LPAs, the TIA process at the local level will be more consistent with INDOT's procedures, and the LPA will contact INDOT when circumstances indicate it is wise to do so. The scoping meeting checklist in the Applicant's and Reviewer's Guides should be a help to LPAs in getting the best result from a TIA.

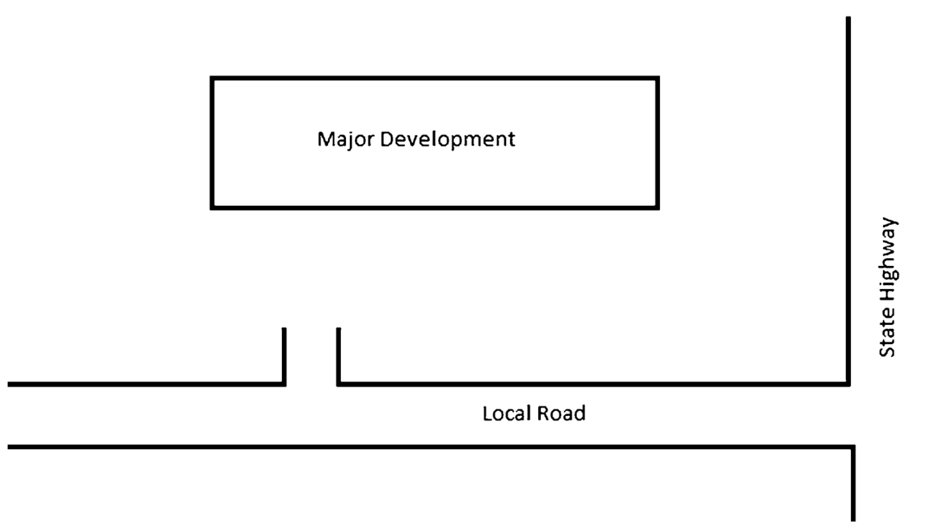


Figure 8.1 Basic example of a development without direct access to a state highway.

2. Publicize the existence of the guides through LPA associations. During the course of this study, the following associations have been contacted:

   - Indiana Association of City Engineers
   - Indiana Association of County Highway Engineers and Supervisors
   - Indiana Street Commissioners Association

   Representatives of these associations have served the research project in advisory roles. The Indiana Local Technical Assistance Program has also indicated that it will help publicize the TIA guides to its local public agency associates.
3. Enlist the assistance of transportation professionals who prepare Traffic Impact Studies for LPAs. It is likely that such professionals prepare TISs for jurisdictions of all types. In any case, the existence of the new TIA guides and the advisability of coordination with nearby jurisdictions can be communicated to practicing engineers through organizations such as the American Council of Engineering Companies of Indiana, Inc. and the Indiana Section of the Institute of Transportation Engineers. An officer of the Indiana Section of ITE served on this project's study advisory committee.
4. Rely on members of the respective INDOT District offices during their interactions with LPAs. District personnel can alert LPAs to the existence of the TIA Guides and stress the importance of giving INDOT early notice of developments that may affect traffic operations on state roadways. At least one INDOT District invites other jurisdictions to scoping meetings, which has helped both sides achieve better coordination and cooperation. The hope is that this practice will create a relationship in which LPAs will include INDOT in situations where early INDOT involvement will be helpful.

The new INDOT Applicant's Guide will state that INDOT should be contacted and included in the initial scoping meetings of major projects that may impact intersections along the state highway system. It is recommended that, if other jurisdictions will be impacted by a development, those jurisdictions also be notified, to ensure that all affected parties can be part of any mitigation measures needed.

8.3 Corridor Protection Area

A corridor protection area sets aside a specified amount of right-of-way for future road expansion. Corridor protection area regulations vary depending upon state law. The Illinois Highway Code (605 ILCS 5/4-510) established corridor protection as a legal process in Illinois (*44*). The Illinois Department of Transportation wished to preserve a corridor for a future north-south expressway between I-80 and I-88.

Corridor protection areas have been used in Indiana as well. The City of Westfield, knowing of INDOT's possible future plans to improve and expand US 31, enacted the US Highway 31 Overlay Zone in March 2011. Its purpose is "to promote the public health, safety, comfort, convenience and general welfare by providing for consistent and coordinated treatment of the properties bordering US Highway 31 in Washington Township, Hamilton County" (*45*). The ordinance covers many land uses issues. Those that affect TIA most directly are:

- The boundaries of the Overlay Zone extend 1320 feet on either side of the right-of-way for United States Highway 31.
- "All uses permitted by right in the underlying zoning districts except [those in] the following [list.]"
- "Landscaping - That portion of the front yard of the lot between the front line and a line which is 30 feet ("Greenbelt Distance") from and parallel to the front line … shall be unoccupied except by steps, walks, terraces, access driveways, lamp posts, signs and other similar structures (excluding a private parking area) permitted by this ordinance …"
- "Frontage Roads - All frontage road intersections within this corridor shall be placed a minimum of 500 feet from the right-of-way of US Highway 31 and shall otherwise conform to all INDOT Standards."

The City of Westfield also enacted the State Highway 32 Overlay Zone in May 2011. Its main features that affect TIA are (*5*) Access Control Requirements and (*6*) Setback Requirements. These provisions make future improvements to and along US 31 and SR 32 less disruptive for both property owner and the roadway agency. However, because land use control is a local matter, INDOT can only encourage and/or facilitate such ordinances.

9. INTERNAL TRIPS

Some developments contain more than one type of land use within the same site. Patrons visiting the development may visit multiple locations in a single visit. An internal trip is a trip that takes place between two locations within the same site, not utilizing off-site streets. In the ITE *Trip Generation Manual* (*11*), land use code 820 for shopping centers directly accounts for internal trips, considering these types of developments are analyzed as a single land use. This is also how the land uses of office park (750) and general office building (710) are handled. The trip generation estimation accounts for internal trips without requiring separate calculations.

These three land uses do not cover all multi-use sites. For those multi-use sites that fall outside the shopping center, office park, and general office building land uses, Chapter 7 of the *Trip Generation Manual* (*11*) provides a methodology to calculate the internal capture rate of a mixed-use site. This methodology is the current recommended practice for calculating internal trips. Internal trips may be subtracted from the total trip generation of a site because they require only one visit to the site. This is important when conducting TIAs, because the reduction in total trip generation may reduce the impacts of a new development and require fewer improvements to handle the increased traffic on the existing road network.

9.1 Pavilions Internal Trip Counts

Internal trip counts were conducted on Saturday October 27, 2012 at The Pavilions shopping center in

Lafayette, Indiana in order to estimate internal trips at the site. The Pavilions is located on the southwest corner of State Route 26 (to the north) and Creasy Lane (to the east). Although The Pavilions is a shopping center that would probably fall under ITE Trip Generation Land Use 820, a data collection effort for an internal capture study at the site was conducted for the following reasons:

1. To attempt to estimate the number or percentage of trips that would be reduced by treating the site, not as a collection of separate stores, but as a shopping center.
2. Because the site has several large out-parcel buildings (see Figure 9.1), The Pavilions may not "behave" like the shopping centers in the ITE database.
3. As one of the newest shopping centers in the Lafayette area, The Pavilions may not "behave" like the shopping centers in the ITE database.
4. Because the researchers had access to the Traffic Impact Study that was done before The Pavilions was constructed, the perspective of a future project could be recreated.
5. It is often instructive to carry out a data collection effort, to gain an appreciation for the benefits and limitations of using data collected by others.

The Pavilions contains a total of 40 establishments, along with 4 vacant retail spaces. For the rest of this chapter, the term "store" will be used to refer to all types of establishments within The Pavilions shopping center, regardless of the type of establishment. Table 9.1 lists the various stores in The Pavilions shopping center alphabetically. At the time the counts were made, Kirklands had not opened. Kirklands has since opened its store.

Four observers were used to watch the entire site and count internal trips. The location of each counter and the approximate corresponding coverage area can be seen in Figure 9.2. To determine the number of internal trips within the shopping center, the observers attempted to track each vehicle and pedestrian from origin to destination. Vehicles entering and exiting the site were ignored, because they would not be making an internal trip at that time. Some movements were assumed to be internal trips based on the vehicle or pedestrian's movement within the site. For example, eastbound vehicles arriving at the corner of Men's Warehouse on the north end of the main strip of stores that made a right turn to parallel the strip of stores were assumed to be internal trips. If these people planned to exit the site, it was assumed that they would use the outer circulation road instead. A visualization of this assumption is shown in Figure 9.1.

Vehicular internal trips were easier to track on the north end of the site where stores are more widely spread out, especially those stores on out-parcels along Creasy Lane. Only pedestrian internal trips were counted in the southern two coverage areas because vehicle movements were difficult to track. Very few pedestrian counts were made in the northern two coverage areas, because many more internal trips were made using a vehicle.

9.2 Internal Trip Count Results

A total of 281 internal trip observations were collected during the two-hour observation period where at least the store at one end of the trip was known, whether it be the origin or destination store. Of the 281 observed internal trips in the two-hour analysis period, both the origin and destination stores were able to be observed for 74 internal trips. A summary of the internal trips where both the origin and destination are known can be seen in Table 9.2. Of these 74 internal trips, 58 were pedestrian walking trips observed in the southern two coverage areas shown in Figure 9.2. It was more difficult to track vehicular trips than

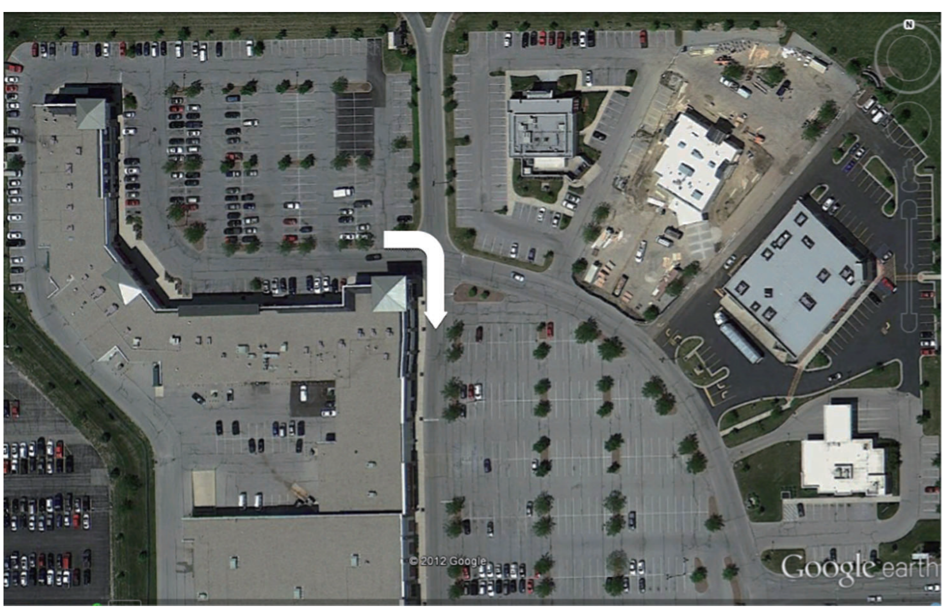


Figure 9.1 Example of an assumed internal trip movement (*28*).

TABLE 9.1
The Pavilions Shopping Center stores

Advantage Dental	Dollar Tree	Kirkland's	Red Lobster
America's Mattress	Dress Barn	Lane Bryant	Sonic
Armed Forces Career Center	En Lai Chinese Kitchen B	Le Nails	Sports Clips
Camille's Sidewalk Café	Famous Footwear	McAlister's	Starbucks
Chuck E. Cheese's	Fiesta Salons	Men's Warehouse	TGI Friday's
Cold Stone	Firehouse Subs	Moe's Southwest Grill	The Game Preserve
Complete Nutrition	Gander Mountain	Office Depot	TJ Maxx
David's Bridal	Gordmans	Old National Bank	T-Mobile
Disc Replay	Hobby Lobby	Payless ShoeSource	Verizon
Discount Tire	HuHot Mongolian Grill	Portrait Innovations	Walgreens

pedestrian internal trips in order to know both the originating store and the destination store.

Forty-four internal trips with both the origin and destination stores known in Table 9.2 occurred between only four stores (Hobby Lobby, Dollar Tree, Dress Barn and TJ Maxx) on the short southernmost strip of stores at The Pavilions. The forty-four trips account for 15.6% of all the counted internal trips during the two-hour time period. Gander Mountain is the store closest to the southernmost strip of stores, and a number of pedestrian internal trips with both to and from the store were able to be tracked and counted. Walgreens was a popular stop for patrons visiting stores or restaurants on the northern end of the site, with thirteen internal trips going to the drug store. Most of the trips to Walgreens, however, did not have a known origin.

A number of internal trips only had a specific known origin or destination, not both. The other end of the trip was known only by the general area from which it started or ended. These internal trips were determined based upon where the patrons or vehicles exited and entered different areas of the shopping center. These internal trips are not included in Table 9.2.

Based on the internal trips that were counted, it is clear that many more patrons walk between stores on the south end of the site than on the north end. One factor that contributed to this may be the locations on the north end that are not currently open for business. A few stores are being remodeled by new tenants. Once the new stores open, there may be more walking internal trips along the northern strip of stores. The types of stores near each other on the southern end of the development may also be more favorable to generating internal trips compared to the northern end. The northern end holds a number of different locations where someone could get food. It is unlikely that patrons

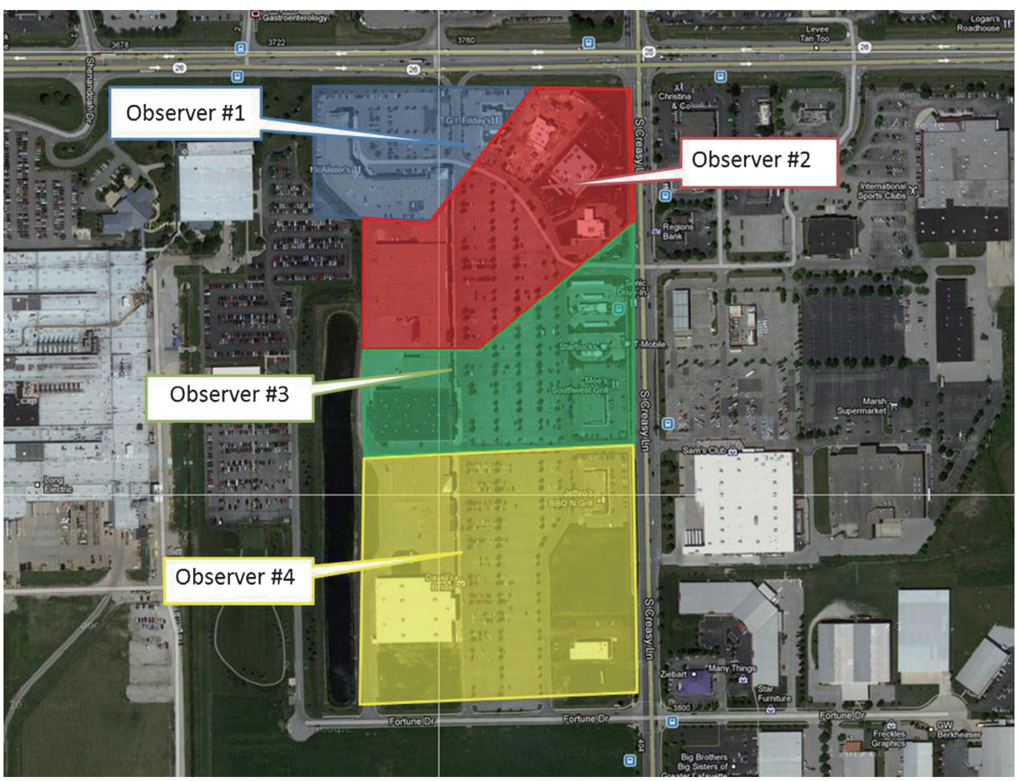


Figure 9.2 Counter locations and approximate coverage areas (*28*).

TABLE 9.2
Internal trips with known origins and destinations

From	# of occurrences	To	# of occurrences
Chuck E Cheese	1	Chuck E Cheese	0
Cold Stone	1	Cold Stone	2
Complete Nutrition	0	Complete Nutrition	1
David's Bridal	0	David's Bridal	1
Disc Replay	1	Disc Replay	1
Dollar Tree	13	Dollar Tree	17
Dress Barn	2	Dress Barn	5
Famous Footwear	1	Famous Footwear	1
Gander Mtn.	5	Gander Mtn.	9
Gordmans	4	Gordmans	2
Hobby Lobby	14	Hobby Lobby	9
HuHot Grill	1	HuHot Grill	0
McAllister's	2	McAllister's	0
Men's Warehouse	2	Men's Warehouse	1
Moe's SW Grill	1	Moe's SW Grill	3
Office Max	2	Office Max	2
Payless Shoes	3	Payless Shoes	4
Sonic	0	Sonic	1
TGI Friday's	0	TGI Friday's	1
TJ Maxx	19	TJ Maxx	12
Verizon	0	Verizon	1
Walgreens	2	Walgreens	1

would go to another restaurant after already eating. The most likely exception is Cold Stone Creamery, which could attract patrons from other stores to purchase dessert. The southern end contains a number of stores, most of which don't compete against each other.

The distribution of internal trips between those made by vehicles and those by walking may be seen in Table 9.3. The number of trips per hour of counting is also shown, broken down by the start of the hour. This is not a definitive split, however. Vehicular trips were difficult to follow because many traveled from one end of the site to another and could not be followed to their destination. This issue also occurred with some of the walking internal trips. Therefore, it is difficult to say how many internal trips of each mode were missed while counts were conducted. Without additional days of data, the number of internal trips and the percentage split between walking and driving can only be considered an initial approximation.

Entering and exiting volume counts were not conducted at the time internal trip counts were conducted; therefore, it is not possible to determine accurately the internal capture rate during the two-hour internal trip observation period. A rough estimate of the percentage of internal trips can be made using the estimated entrance counts presented in Table 9.4.

TABLE 9.3
Internal trips by mode and hour

Mode	#	Hour beginning	#
Pedestrian	152	12:00 PM	118
Vehicular	124	1:00 PM	158

The entrance estimates in Table 9.4 are for the PM peak period taken from the 2003 traffic impact study, while the internal trips were counted beginning noon on a Saturday. The PM peak was selected for driveway counts because fewer stores (especially restaurants) at the site are open during the AM peak; therefore, the PM peak would more closely resemble conditions on a weekend during midday. During the PM peak period, the total estimated site traffic was 1620 trips. The 281 counted internal trips would be 17.3% of the total site trips. This percentage of internal trips may be significant because, if these internal trips had instead been classified (in a prospective traffic impact study) as single-purpose trips, 281 more driveway counts would have been charged to the site, predicting (incorrectly) that much more of a strain on the existing road network and perhaps requiring the developer to pay more to mitigate traffic impacts.

It is most likely that the total number of internal trips during the two-hour counting period is somewhat underestimated. While some of the assumed internal trips may not have actually been internal trips, a similar amount were most likely missed while tracking other

TABLE 9.4
Pavilions TIS estimated driveway counts (*46*)

Entrance	AM in	AM out	PM in	PM out
SR 26 entrance	63	4	229	22
International Square entrance	104	87	333	500
Sam's north entrance	36	38	116	212
Fortune Drive entrance	195	8	27	181
Total	**398**	**137**	**705**	**915**

internal trips. Also, none of the observers were able to observe possible trips between the two very small strip malls on out-parcels along Creasy Lane. Because there are more opportunities to miss internal trips than miscount them, it is most likely safe to assume the collected internal trip counts underestimate the true number of internal trips made at The Pavilions. The counts collected do, however, provide a good initial approximation.

9.3 Problems with Data Collection

The geometry of the site is not conducive to gathering internal trip counts. The main stretch of stores is a long line. Many people visiting the site would drive from one end to the other in order to make a trip to a second store. Others would walk between stores, but the long distances between stores made it difficult to determine where people came from and where they were going to. One observer could only watch for so long and so far before he/she had too many other shoppers to watch.

Gathering an accurate estimation for The Pavilions shopping center would be difficult. The addition of more observers may provide better estimates of pedestrian activity, but patrons conducting internal trips using vehicles are much more difficult to track because they go greater distances and would pass through the view of multiple observers. The use of multiple video cameras to track internal trips would be another option. Given the size and number of patrons of the site, however, tracking the internal trips through multiple video feeds could prove cumbersome as well. A number of cameras would be needed in order to capture all angles needed to track internal trips, and then someone would have to follow each vehicle or individual from each camera through other cameras to determine internal trips.

A method that would probably yield the most accurate internal trip counts would also be the most intrusive method. An observer would be stationed at the entrance to each store within the site and ask each individual or group where they had come from, whether it is from home, somewhere within the site, or elsewhere. This method is suggested in Section 7.7 of the ITE *Trip Generation Manual* (*11*). The four "Suggested Interview Questions" in Figures 7.6 and 7.7 of the ITE *Trip Generation Manual* (*11*) may not take a lot of a shopper's time, but it is not something that a shopper views as a positive experience. In the 1991 survey to estimate pass-by trips, 200 patrons at the Eastway Plaza Shopping Center were interviewed and all 200 provided usable answers. It is unlikely that a response rate anything near 100 percent would happen in 2013.

9.4 Store Selectivity and Store Compatibility

If internal trips could be completely and accurately counted, the data could provide more information besides the number of trips that could be deducted from the total trip generation for the development. Because both the origin and destination stores would be known, the number of internal trips to and from each store within The Pavilions could be determined. If certain stores (or store types) had a disproportionate number of internal trips being made between them (especially if made by vehicle not by foot), shopping center management could consider placing such stores (or store types) closer together at the observed shopping center or at future ones.

Along with identifying compatible stores, it might be possible to analyze the impact of distance between stores on internal trips. Such an analysis may determine whether or not two stores being located closer together within a development could generate more internal trips, or if distance does not have a significant effect upon internal trips between the stores. Currently at The Pavilions, a number of internal trips are conducted by patrons driving their vehicles from one from store to store, based upon the internal trips counted by the observers. A majority of the pedestrian internal trips were observed along the southern strip of stores that includes: Hobby Lobby, David's Bridal, Dollar Tree, Dress Barn and TJ Maxx. If some of the stores located further from this southern strip of stores were closer, would a higher number of internal trips occur between them?

To determine the effect distance has on internal trips, more internal trip counts at other shopping center developments would need to be collected to obtain more reliable results. The shopping centers would need to have the type of stores for which the effect of distance was being analyzed. It would be very unlikely to find shopping centers with all the same stores as The Pavilions; therefore, certain stores instead of entire shopping centers would most likely have to be selected for study. The number of observers and person-hours needed to conduct the studies accurately (if one observer posted outside each store's entrance was the selected method) at multiple sites is the major obstacle to collecting the necessary data. Internal trip counts on multiple days and during multiple time intervals would provide more reliable internal trip estimates. The comparison between sites still may be difficult to make depending on the effect of having different stores at different sites has on each site's internal trips.

Both store compatibility and the effect of distance between stores on internal trips may affect how developers design and plan future. If compatible store types can be determined, developers may attempt to bring in more compatible stores to their developments to increase site use or increase the number of internal trips. The lower trip generation rate may reduce the site's impact on the surrounding road network enough to not require intersection improvements and/or reduce the amount of impact fee required (if a fee was in place). Developers may also try to place compatible stores closer to each other in order to increase internal trips. It is not certain how selective developers are or are able to be when determining store locations within their developments. If developers attempt to place compatible stores near each other, it may induce more patrons to visit the site. The amount of induced trips would be difficult to quantify if they did occur.

In order to quantify any effects from store placement at a shopping center such as The Pavilions, the shopping center would have to be able to adjust the locations of stores within its site. The companies in a shopping center may not be very favorable to relocating within the site. Shopping centers with easily-removable semi-permanent walls may be the style of shopping center where such an analysis could be performed. For the near future, any analysis of store compatibility may make developers more selective about where to locate certain types of stores, but existing developments most likely will not be affected.

9.5 Lessons Learned

As a result of attempting to count internal trips at The Pavilions shopping center, some understanding of the steps necessary to gather accurate internal trip counts was gained. For the observers counting internal trips, it became very obvious how difficult it was to visually track internal trips from origin to destination within a shopping center. Even with more observers, the size of the site would make it difficult to conduct counts. Theoretically, it would seem the method to obtain accurate internal trip counts would be placing an observer at the entrance to each store within the shopping center asking entering patrons from whence they came; however, this and other possible methods were not tested for comparison with the method used. It was also learned that the ITE *Trip Generation Manual* (*11*) Volumes 2 and 3 do not contain equations or data to use to predict the trip generation for many of the individual store types within a shopping center. These store types may be absent from the ITE *Trip Generation Manual* because they do not commonly locate in stand-alone buildings. If the equations and/or data had been available, a comparison of expected vs. actual internal trips could have been made.

A few factors could have significant impacts on internal trips at shopping centers. Store type and location within a shopping center may impact the site's total trip generation and number of internal trips. This would directly correlate to whether the site's total trip generation would be over or underestimated. The location of stores may also induce more trips to the site. It would be interesting to conduct trip generation counts at shopping centers once fully developed and compare the counts to what the predicted total trip generation prior to construction was for the shopping center.

10. SUMMARY

This research report is written to provide background and support for the updated Applicant's Guide to Traffic Impact Studies and Reviewer's Guide to Traffic Impact Studies (*43,47*). The original Applicant's Guide and Reviewer's Guide were published in 1992. The Guides have helped streamline and standardize the practice of Traffic Impact Analysis (TIA) in Indiana. The primary purposes of this project were to:

A. Update the Applicant's Guide and Reviewer's Guide to take into account changes in methodology, references, and operating environment that have occurred since the publication of the 1992 Guides.
B. Make the Guides applicable to jurisdictions in Indiana besides INDOT, as part of the effort to foster cooperation and coordination between multiple jurisdictions that may be affected by a new development.
C. Determine whether any changes to the *Indiana Administrative Code* needed to be promulgated as the code pertains to Traffic Impact Analysis.
D. Investigate and evaluate new intersection designs that may be part of the solutions to increased traffic from a new development.

The updated Applicant's Guide to Traffic Impact Studies and Reviewer's Guide to Traffic Impact Studies are designed to facilitate the practice of Traffic Impact Analysis in Indiana. Each guide is intended to provide its user with a concise set of parameters within which the applicant and reviewer can agree upon, early in the process, those procedures that will best fit the proposed development. Elements in the checklists for the scoping meeting and the TIA report (if there is to be one) can be selected. Within reasonable guidelines, the applicant (who is usually the consulting engineer representing the developer) can carry out the TIA using methods that the applicant thinks are appropriate.

The changes made in the Applicant's Guide and the Reviewer's Guide are such that changes to the *Indiana Administrative Code* are not necessary. If, however, INDOT wished to implement traffic impact fees, some changes to Indiana Code may be needed. At a minimum, the Code would need to be reviewed by qualified legal staff to determine how traffic impact fees could be applied at the state level.

The main themes of these Guides are efficiency and clarity. By providing both applicants and reviewers with information explaining much of what is expected in a traffic impact study, it is expected that the amount of time and effort needed to prepare and review the traffic impact study will be reduced. Also, by getting all parties together early in a project, the need to modify a design can be avoided. The agreements that result from such early communication are likely to produce a project that suits the needs of the developer without adversely affecting the nearby transportation system. A transportation system that works well is also in the best interests of the developer.

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APPENDIX. TIA SURVEY RESPONSES

TABLE A.1
Consultant survey responses

Time stamp	1. How experienced with TIAs would you consider your company?	4. Please cite any specific cases or personal experiences involving TIAs that would be instructive for the researchers to know about.	2. Which resources does your firm use when conducting a TIA?	Please provide your name, phone number and e mail address in the space below.	3. What change s and/or update s to the INDOT TIA Guides would you like to see made?
7/23/2012 11:28:17	Very experienced		INDOT Applicant's Guide to Traffic Impact Studies, ITE Recommended Practice: Traffic Impact Analyses for Site Development, INDOT Access Management Guide, ITE Trip Generation Report, INDOT Permits Manual	Hardik Shah, PE, PTOE 317-547-5580 hshah@structurepoint.com	**Growth Rate.** It is important to have coordination with the planning agencies/MPO to identify the use of an appropriate background growth rate for the study area. Many times the background growth rate can be a deciding factor in determining the absolute capacity needs for the corridor over and above the planned development. **Recent Traffic Counts.** Recent economic downturn has an impact on the travel pattern and the trend has been changing constantly. Hence an emphasis on using fairly recent traffic counts (data collection) is critical.
7/23/2012 12:15:51	Very experienced		INDOT Applicant's Guide to Traffic Impact Studies, ITE Recommended Practice: Traffic Impact Analyses for Site Development, INDOT Access Management Guide, ITE Trip Generation Report, INDOT Permits Manual	Jill Palmer, 317-826-7129 jpalmer@schneidercorp.com	The "Applicant's Guide" is appropriately named; I suggest a companion document, "Reviewer's Guide" with instructions and a checklist to assist in the review process, with more detail than is provided Ch. 17 "Staff Review." The current "Applicant's Guide" has served me well as both as a beginner and as an experienced study preparer, but there is little guidance for the reviewer. Also, revise mention of "accidents" in the Guide to "crashes."
7/23/2012 13:28:10	Very experienced	Several examples of various types of developments across the Indiana. While at A&F I have completed or have overseen the preparation of over 500 traffic studies and would be more than willing to share my experiences.	INDOT Applicant's Guide to Traffic Impact Studies, ITE Recommended Practice: Traffic Impact Analyses for Site Development, INDOT Access Management Guide, ITE Trip Generation Report, INDOT Permits Manual	Matt Brown A&F Engineering 8365 Keystone Crossing, Suite 201 Indianapolis, IN 46240 317-202-0864	More consistency with the design guide—updated more often. Defined acceptable Los criteria based on location maps. Defined process and or rates to be used for pass by and internal trip procedures. Scope defined for when a TOA is required vs a TIA. Size scopes defined by the area of study—for instance TIA should look at all major intersections within a mile each direction from the site. More integration with the access management guidelines.

TABLE A.2
LPA survey responses

Time stamp	1. How experienced with TIAs (Traffic Impact Analyses) would you consider your agency?	If you answered "Other" to Question 3, please describe brie fly the TIA methods your agency uses.	2. Who re views TIAs for your agency?	5. Please cite any specific case s or personal experiences that would be beneficial for the researchers to know about.	Please provide your name, agency, phone number and email address in the space below.	3. Whichresources do you use when reviewing a TIA?	4. Are there any difficulties your agency encounters regarding TIAs ?	Brief Comments
5/16/2012 7:50:12	Somewhat experienced	Typically TIA's are conducted by the applicant or their engineer. We prefer they use Traffic Engineering, Inc. whenever possible but we are not allowed to specify a particular firm. Therefore, we give them a list of three firms which includes TEI plus two other firms located in Mexico.	Hired consultant, applicant or their engineering firm	Jon - In my experience, I have found an early mtg with INDOT to agree on scope of analysis to be helpful for a couple reasons: (1) reduces chance of having to resubmit TIA and (2) helps client understand issues important to INDOT while there is still opportunity to adjust site plan. Clients (applicants) typically have no idea what a TIA is or why it costs more than $100. A mtg with INDOT helps them understand the importance and benefit for their development.	Chet Skwarcan, PE Traffic Engineering, Inc. etc.	INDOT Applicant's Guide, INDOT Reviewer's Guide, ITE Recommended Practice: Traffic Impact Analyses for Site Development, Magic 8 Ball.	Yes	More graphics please and include exec summary. Also, early review/ approval of trip gen and trip dist would save redo.
5/29/2012 7:20:58	Limited or not experienced		We have not yet conducted a TIA.	I know nothing about TIA's.		Our agency does not review TIAs.	No	If we don't have them, can't have difficulty with them. I am not saying we shouldn't have them, just never have. If we had one, I wouldn't know where to begin with reviewing it.
5/30/2012 15:52:20	Somewhat experienced		Done in-house.		John E. Ayers, P.E. Hendricks County Engineer 317-745-9235 jayers@co.hendricks.in.us	INDOT Guide to Traffic Impact Studies - Applicant's or Reviewer's, INDOT Access Management Guide	Yes	Interpreting results can be difficult when they are submitted in varying formats or when they seem to be incomplete (selective data omission.)

TABLE A.2
(Continued)

Time stamp	1. How experienced with TIAs (Traffic Impact Analyses) would you consider your agency?	If you answered "Other" to Question 3, please describe brie fly the TIA methods your agency uses.	2. Who re views TIAs for your agency?	5. Please cite any specific case s or personal experiences that would be beneficial for the researchers to know about.	Please provide your name, agency, phone number and email address in the space below.	3. Whichresources do you use when reviewing a TIA?	4. Are there any difficulties your agency encounters regarding TIAs ?	Brief Comments
6/5/2012 9:26:33	Limited or not experienced		Hired consultant		Jodi Dickey Town of Fishers 317.595.3429 (direct) dickeyj@fishers.in.us	INDOT Guide to Traffic Impact Studies - Applicant's or Reviewer's, ITE Recommended Practice: Traffic Impact Analyses for Site Development	Yes	Explaining some of the technical aspects and the benefits as well as constraints to town council and plan commissioners can be a bit difficult.

TABLE A.3
INDOT district survey responses

Time stamp	1. In what way are you involved in the review of Traffic Impact Studies?	3. What changes and/or additions should be made to the INDOT Guides to Traffic Impact Studies?	4. Please cite any specific cases or personal experiences involving TIAs that would be beneficial for the researchers to know about.	Please provide us with your name, job title, phone number and email address in the space below.	2. Which references do you use when reviewing Traffic Impact Studies?
6/11/2012 18:14:31	I project manage all private development that occurs within INDOT right of way and the impact of and to traffic generated by the development. I conduct analysis of traffic volumes to determine the design criteria for road improvements as a result of private development.	Possible additions pertaining to the possible use roundabout construction as opposed to signal construction.	Cherry Street and SR 37, Noblesville, Indiana	Jack Kimmerling INDOT Greenfield District Permit Manager 317-467-3492 jkimmerling@indot.in.gov	INDOT Applicant's Guide to Traffic Impact Studies, INDOT Reviewer's Guide to Traffic Impact Studies, Indiana Access Management Guide, INDOT Permits Manual, Indiana Administrative Code, ITE Recommended Practice: Traffic Impact Analyses for Site Development, ITE Trip Generation Report
6/12/2012 8:24:21	Local public coordination of federally funded projects.	For my coordination purpose on projects, the study is use to determine the most needed projects.	Not aware of any.	Susie Kemp Local Programs Coordinator 765-361-5228 skemp@indot.in.gov	I am not involved in the review of Traffic Impact Studies.
6/12/2012 9:12:33	I am not directly involved however due to supervising the permits department I occasionally review the TIS in order to understand the detail of the permit request.			Valerie Cockrum Technical Services Director vcockrum@indot.in.gov	INDOT Permits Manual
6/12/2012 9:50:24	When a permit is applied for, we get with our District Traffic Engineer to coordinate what kind of study is done. Studies are submitted through our permits, and we discuss with our Traffic Section.			Gary Bowser; Crawfordsville District Permit Manager 765-361-5249 gbowser@indot.in.gov	My Section relies on the Traffic Engineering Section
6/12/2012 16:26:22	TIS are used to assist to determine auxiliary lane requirements for new commercial driveway permit applications.			Mack Hosack INDOT Fort Wayne District Permit Engineer 260-969-8254 mhosack@indot.in.gov	INDOT Permits Manual, Indiana Administrative Code, Limited - Review done by District Traffic Engineer
6/13/2012 7:47:51	I am responsible for the review and approval of TIS's submitted to the District. My staff engineer reviews the actual study under my supervision.	An updated checklist for the scoping meeting would be helpful. Analysis section should reference Synchro as the primary analysis tool for intersections and progression analysis.		Dana Plattner District Traffic Engineer 260-969-8233 dplattner@indot.in.gov	INDOT Applicant's Guide to Traffic Impact Studies, INDOT Reviewer's Guide to Traffic Impact Studies, INDOT Permits Manual, ITE Trip Generation Report

TABLE A.3
(Continued)

Time stamp	1. In what way are you involved in the review of Traffic Impact Studies?	3. What changes and/or additions should be made to the INDOT Guides to Traffic Impact Studies?	4. Please cite any specific cases or personal experiences involving TIAs that would be beneficial for the researchers to know about.	Please provide us with your name, job title, phone number and email address in the space below.	2. Which references do you use when reviewing Traffic Impact Studies?
6/13/2012 13:30:37	Primary Reviewer of TIS.	Use of the "M" word on page 20, Parts C, D, & E of Reviewer's Guide. Most everywhere else, the Reviewer's Guide is referred to as "this guide." Incorporate the use of software packages for traffic analysis. In the Fort Wayne District, it is almost always Synchro and SimTraffic software.		Dirk Schmidt Traffic Investigations Engineer Fort Wayne District 260-969-8287 DSchmidt1@indot.IN.gov	INDOT Reviewer's Guide to Traffic Impact Studies, INDOT Permits Manual, ITE Trip Generation Report, ITE Trip Generation Handbook, INDOT Design Manual
6/13/2012 14:29:20	For several years I was the district reviewer of the TIAs and or TOAs, for our District Permits section. Not as much now sine we have a District Traffic Planning engineer who does this. I may answer his questions along the way if he has any.	The biggest/overall general change I see that is needed, is that Applicant's Guide and the Reviewer's Guide should be more closely akin to the Indiana Design Manual. A lot of times while conducting a review I would notice definite differences if looking in the guides versus looking in the manual. They need to be coordinated and updated. I know there have been great strides in making sure the IDM is updated, etc. The guides have not been updated since 1996.	My comments and observations, noted above are based on an overall usage of both documents and comparing them directly against each other. Not necessarily a specific case.	Mr. Randall L. Phegley, P.E. Vincennes District Traffic Investigations Engineer 812-895-7458 rphegley@indot.in.gov	INDOT Applicant's Guide to Traffic Impact Studies, INDOT Reviewer's Guide to Traffic Impact Studies, ITE Recommended Practice: Traffic Impact Analyses for Site Development, ITE Trip Generation Report
6/13/2012 15:30:17	The district permit (regulatory) section was under the system assessment section. Currently involvement of the effect of the study on the asset of the infrastructure. I do not directly review the TIS, my interest in the results of the study.	Clarification between TIS & TOA. Include Access Management.	SR 162 @ Holiday World. SR 57 in Washington.	Khalil Dughaish System Assessment Manager INDOT-Vincennes District KDughaish@indot.in.gov 812-895-7377 office 812-459-4929 cell	INDOT Applicant's Guide to Traffic Impact Studies, INDOT Reviewer's Guide to Traffic Impact Studies, Indiana Access Management Guide, INDOT Permits Manual, Indiana Administrative Code
6/14/2012 17:53:30	I will read them when they are part of a Permit Application.	The simple fact that they have not been updated in 15+ years should be reason enough. I was aware of the Applicant's Guide, but didn't know there was a reviewer's guide until I read this. Is the reviewer's guide on the intranet?	Nothing comes to mind, but I am happy to help in any way I can.	Bill Meeks Technical Services Director - LaPorte 219-325-7470 bmeeks@indot.in.gov	None
6/15/2012 9:14:26	I review the Traffic Impact Studies mainly based on the traffic safety and mobility aspects.	Private consultants believe that INDOT is supposed to supply them with crash data. There is confusion between who is supposed to collect the data.		Damon Brown, EIT Traffic Planning Engineer - Vincennes District Office Office 812-895-7457 812-786-7405 cell DaBrown@indot.in.gov	INDOT Applicant's Guide to Traffic Impact Studies, Indiana Access Management Guide, INDOT Permits Manual, ITE Trip Generation Report

TABLE A.3
(Continued)

Time stamp	1. In what way are you involved in the review of Traffic Impact Studies?	3. What changes and/or additions should be made to the INDOT Guides to Traffic Impact Studies?	4. Please cite any specific cases or personal experiences involving TIAs that would be beneficial for the researchers to know about.	Please provide us with your name, job title, phone number and email address in the space below.	2. Which references do you use when reviewing Traffic Impact Studies?
6/15/2012 10:10:42	I am not involved in the review of Traffic Impact Studies.			Marcia Blansett Local Program Coordinator 219-325-7564 mblansett@indot.in.gov	I am not involved in the review of Traffic Impact Studies.
6/18/2012 9:39:55	Prior to a scoping meeting for an application I reference them to review the Applicant's Guide to Traffic Impact Studies. George Kopcha and Bill Smith tell the applicant what information will be required.			Paula Gibson, Permit Investigator 765-361-5607 pgibson@indot.in.gov	INDOT Applicant's Guide to Traffic Impact Studies, I am not involved in the review of Traffic Impact Studies.
6/18/2012 9:48:10	I sit in on the TIS scoping meeting, take notes.	Unknown.	Unknown.	Carla Sheets, Permit Clerk 765-361-5237 sheets@indot.in.gov	INDOT Applicant's Guide to Traffic Impact Studies, INDOT Permits Manual
6/18/2012 10:29:48	TIS is provided to us with a commercial driveway application.	Depends on our traffic engineers.		Leatha Coffing Permit Investigator 765-366-2151 lcoffing@indot.in.gov	I am not involved in the review of Traffic Impact Studies.
6/19/2012 13:08:08	I do not review the studies, but am involved during the permitting process.			Terri Griffin Permit Investigator 765-361-5254 tegriffin@indot.in.gov	I am not involved in the review of Traffic Impact Studies.
6/22/2012 10:29:50	I assist in defining the scope of studies. I supervise the TIS reviewer (George Kopcha at Crawfordsville) and I am responsible for final acceptance of the study. We will request clarification and revision when necessary due to our review. I am involved in requiring improvements based on the results of a TIS.	More detail regarding alternative intersection design (roundabouts, etc.). More detail regarding signal spacing/ intersection spacing based on type of intersection. More guidance on access control (frontage roads and backage roads). When could INDOT access be denied or limited through development of off system access? When should a developer share in the costs of future improvements that will be necessary partially due to traffic generated by their development (i.e., future signal)? Last one in usually pays full cost but cost sharing needs to be discussed.	Two areas where access issues have been discussed are US36 in Avon and US 40 in Plainfield. In both cases, local government would like assistance from INDOT in limiting the need for additional traffic signals on these corridors.	Bill Smith Crawfordsville District Traffic Engineer 765-361-5631 bsmith@indot.in.gov	INDOT Applicant's Guide to Traffic Impact Studies, INDOT Reviewer's Guide to Traffic Impact Studies, Indiana Access Management Guide, INDOT Permits Manual, ITE Trip Generation Report

TABLE A.3
(Continued)

Time stamp	1. In what way are you involved in the review of Traffic Impact Studies?	3. What changes and/or additions should be made to the INDOT Guides to Traffic Impact Studies?	4. Please cite any specific cases or personal experiences involving TIAs that would be beneficial for the researchers to know about.	Please provide us with your name, job title, phone number and email address in the space below.	2. Which references do you use when reviewing Traffic Impact Studies?
6/25/2012 16:36:30	I review Traffic Impact Studies as they pertain to commercial driveway permit applications along State Highways in the La Porte District. The key components I typically review are comparing proposed traffic volumes against MUTCD Traffic Signal Warrant Criteria and general Level of Service information to confirm a proposed development is not going to cause traffic backups or potential traffic safety issues.	I have no proposed changes or additions to suggest at this time.	No specific locations stand out at this time.	Mike Yacullo La Porte District Traffic Engineer 219-325-7555	INDOT Reviewer's Guide to Traffic Impact Studies, ITE Trip Generation Report
7/2/2012 11:25:53	Investigators in the Crawfordsville District Permits Group will request that I conduct a TIS scoping meeting and that I review the TIS for major commercial drive applications. I report to the District Traffic Engineer, Bill Smith.	1. HCM 2010 has a new Urban Streets chapter. Some (or most) of the new calculations and methodology is applicable for TIS. 2. Usually the TIS evaluates only one or two nearest signals. It would be highly unusual that any TIS would evaluate a signal system. Developers have not been demonstrating how the added trips (and, if applicable, an additional signal) affect progression. When I requested for developers to go an extra signal beyond, thinking that the added traffic affects the far-away signal, I was told that as we go further away from the development the added traffic becomes low and that it does not need to be evaluated. At what point does the added traffic become low enough that the signal does not need to be evaluated 3. We had a draft access management guide that had three tiers of roadways. We need stronger guidance. The implication is that if the roadway is Tier 2 or Tier 3, then direct access to the state road is not to be discouraged.	1. Applications for major commercial drives near interchange ramps, two locations: SR 39 at 170 and SR 267 at 165. These are truck stops. SR 267 at 165 is a large development and the public road was newly aligned so that the potential signal would be 1200 ft from the ramp. But at the SR 39 interchange, access to the truck stops (the truck stop to the south already existed; to the north is the new truck stop) are 750 ft from the ramps. 2. The 1-acre lot adjacent to other 1-acre commercial lots, each having their own access drive. When we talk about sharing a drive, the response is usually that the developer does not want to share a drive. 3. The 5-acre lot requesting direct access to the state highway and has a second access, such as to a local road or to a different commercial development.	George Kopcha Transportation Planning Engineer INDOT Crawfordsville 765-361-5634 gkopcha@indot.in.gov	INDOT Applicant's Guide to Traffic Impact Studies, INDOT Reviewer's Guide to Traffic Impact Studies, INDOT Permits Manual, ITE Trip Generation Report, Indiana Design Manual, HCM, HCS, Synchro

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,500 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at: http://docs.lib.purdue.edu/jtrp

Further information about JTRP and its current research program is available at: http://www.purdue.edu/jtrp

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