Incorporating Data-Driven Safety Analysis in Traffic Impact Analyses: *A How-To Guide*

U.S. Department of Transportation
Federal Highway Administration

EDC


Credit: Fotosearch

Introduction

Background

Traditional crash and roadway analysis methods mostly rely on subjective or limited quantitative measures of safety performance. This dependence makes it challenging to calculate safety impacts alongside other criteria when planning projects. Data-Driven Safety Analysis (DDSA) employs newer, evidence-based models that provide State and local agencies with the means to quantify safety impacts similar to the way they do other impacts such as environmental effects, traffic operations, and pavement condition. DDSA provides reliable estimates of an existing or proposed roadway's current and future safety performance and helps agencies make more informed decisions, better target investments, and reduce crashes occurring on their roadways. This guide demonstrates how transportation agencies and consultants can incorporate DDSA into routine traffic impact analyses (TIA).

TIAs are engineering studies that estimate the impacts of a proposed traffic generator (e.g., new residential or commercial development) on the transportation system. Traditionally, TIAs focused on the capacity and operational aspects of increased traffic volumes, assuming that improvements to address operational impacts would also provide safety benefits. However, independent safety analysis was not usually done, resulting in safety impacts being overlooked, and opportunities for safety enhancements being missed. This was often due to the difficulty of quantifying future safety performances and their impacts. Additionally, there were challenges associated with the assumed level of effort (e.g., cost) and assumed experience required to conduct a safety analysis. With the advent of these new models and tools, practitioners can now more readily integrate DDSA into the TIA process.

Benefits of Using DDSA in Traffic Impacts Analyses

Incorporating safety into TIAs will help highlight safety issues during the project development phase before any construction is completed, thereby enabling the development of safer roadways. Although crash reduction is a primary goal for the transportation agency and the public, safety analysis is more about finding reasonable solutions that mitigate the impacts of a proposed development. From the land developer's perspective, crashes cause delays and can make it more difficult to get customers or residents into the development, so any effort that reduces crashes is a benefit to the developer. Furthermore, safety driven improvements will help agencies be more receptive to the development overall and therefore may help facilitate and expedite the necessary approvals to move the project forward. From the transportation agency's perspective, incorporating safety into a TIA can help the agency achieve targeted benchmarks for a reduction in crashes and fatalities, which are often part of initiatives such as Vision Zero and Toward Zero Deaths. Additionally, implementing safety as part of the TIA can provide the citizens and roadway users a more comfortable and safer environment as they commute home to loved ones.

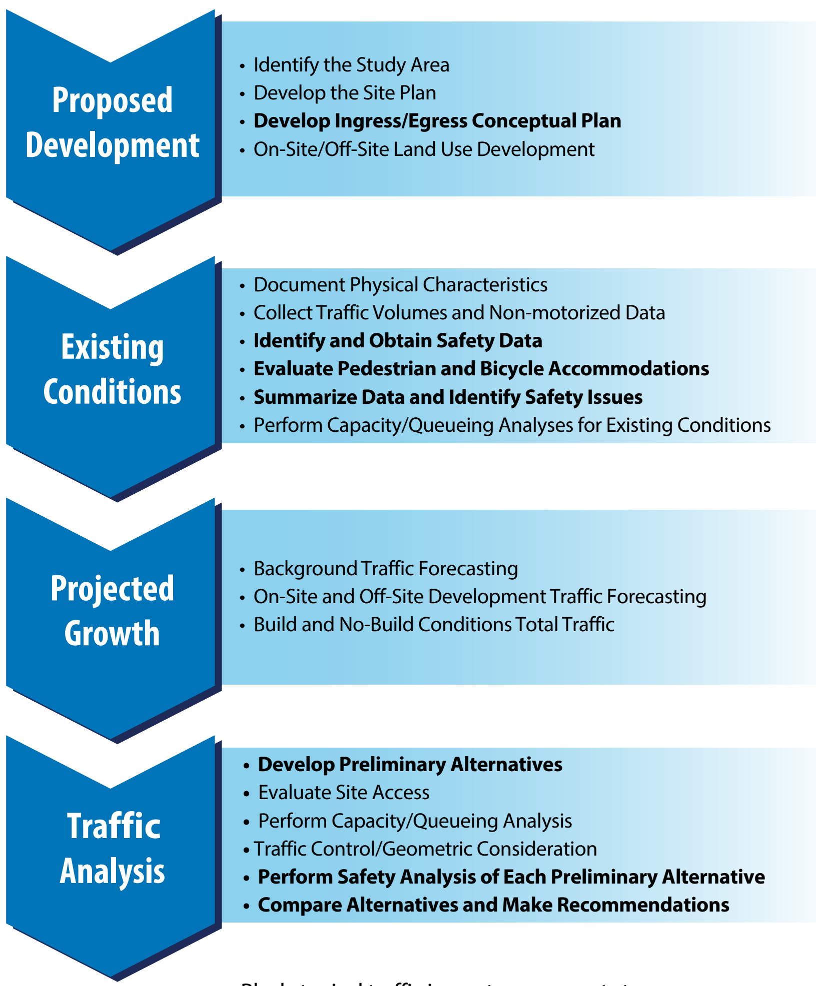
Credit: Fotosearch

Safety Tools Used

There are a variety of methods that transportation agencies and consultants can use to integrate DDSA into TIAs. This guide provides a high-level overview of how to conduct safety analyses using readily available tools and data. AASHTO, FHWA, and the private sector have developed several tools for conducting robust analyses, and more information on these tools can be found at Data-Driven Safety Analysis Resources - DDSA Toolbox. In addition, some state and local agencies have their own customized tools. Therefore, the analyst conducting the safety analysis should check with the agency about tool and data availability.

Overview of DDSA in Traffic Impact Analyses

Figure 1 shows the integration of DDSA into the typical TIA process, with the DDSA related elements shown in bold lettering. This example represents a typical TIA with a proposal for future development. At the beginning of the TIA process, the applicants for the project contact localities and begin their preliminary due diligence and identification of the study area. In doing so, the analyst develops a site plan and an ingress/egress conceptual plan. Next, the analyst will begin evaluating existing conditions by thoroughly reviewing physical characteristics, collecting traffic data, as well as evaluating existing operations and determining the level of service. Additionally, the analyst will begin to identify and obtain safety data and evaluate pedestrian and bicycle accommodations. The analyst will use obtained safety data and will, in turn, develop visual aids from the data to identify safety issues. Next, the analyst will evaluate existing intersection operations and capacity and project volumes into the future conditions. These projected volumes will be used to evaluate the future no-build alternative and all build alternatives. Once the analyst has an understanding of the existing and future no-build conditions, preliminary alternatives are developed and tested from an operations and safety perspective to understand the implications of the new development. The analyst will not only utilize the results of these analyses to compare the alternatives, but will typically finalize the comparison by conducting a benefit-cost analysis. Based upon these results and the build conditions, the analyst would make recommendations to improve both operational and safety impacts of the proposed development.



Black: typical traffic impact assessment step

Bold: opportunity to integrate safety

Figure 1: Opportunities to Integrate Safety in the Typical Traffic Impact Assessment Process

Application of DDSA to Traffic Impacts Analyses

The following sections represent DDSA action items, within the existing TIA process, that will implement safety into TIAs. These nested action items, as outlined in bold lettering, will be conducted in the order as shown in **Figure 1.**

Proposed Development

Action Item: Develop an Ingress/Egress Conceptual Plan

The first step is to develop an understanding of the existing ingress and egress locations for the existing access way. This requires either observing the conditions in the field or discussing adjacent development site access with local jurisdictions. Conceptualizing these entrance and access points will help gain a preliminary understanding of the existing conflict points or issues related to the intersection and can help provide evidence supporting crash data that may be unclear. Additionally, it is important to consider this conceptual plan as part of the analysis further in the TIA. Relying on existing entrances or intersection should not be the assumed path for the development; however, it should be carefully considered when proposing new driveways. The analyst should consider the following when locating proposed access points:

- *The number of access points should be limited to minimize traffic conflicts.*
- *The ingress/egress conceptual plan should align opposing access points where possible.*
- *The location of access points should maintain adequate spacing between adjacent streets and driveway intersections.*
- *The potential for joint and/or cross access between adjacent properties.*

It is also important to note that, although the development of an ingress/egress conceptual plan occurs early in the TIA process, it is not a fixed project element and should be revised if safety and operational issues are detected after analysis.

Existing Conditions

Action Item: Identify and Obtain Crash Data

The analyst should next obtain safety data to review existing conditions. Typically, analysts will use three to five years of crash data, and this should be discussed with the road owner before beginning. To conduct a safety analysis, it is crucial to review and understand the crash narratives. While the level of detail within crash records varies depending on the reporting agency and officer, at the very minimum, obtaining the when, where, and what type of crash are helpful in conducting the safety analysis. Additionally, details of the crash severity and causation are also useful. Analysts can typically obtain crash data from the local transportation agency or the State DOT. If the data is not available from either of those sources, the analyst can contact local law enforcement officials to request copies of the crash reports or a database of consolidated crash data.

Action Item: Evaluate Pedestrian and Bicycle Accommodations

When proposing any development, it is essential to consider how a project impacts both motorized and non-motorized users. Little or no actual crash data that reveals trends involving vulnerable road users means the analyst must consider the nature of the development and its proximity to other land uses where walking and biking may occur. Evaluating other considerations, such as bus stops and pedestrian facilities, is also important to gain an understanding of the types of pedestrian volumes and uses of adjacent area pedestrian facilities. This will provide the analyst with insight as to what additional facilities should be implemented as part of the development that will reduce existing crashes or mitigate potential future crashes involving non-motorized users.

Action Item: Summarize Data and Identify Safety Issues

With the data collected, the next step is to present the data visually to understand problematic locations and recurring crash types. The analyst could accomplish this step in several ways, including plotting crashes on a pin map, developing a collision diagram, or using online geographic information systems (GIS) to pinpoint crash locations. Regardless of the method chosen, summarizing the data will support the identification and analysis of safety issues.

One approach includes developing collision diagrams using aerial imagery and placing symbols at the crash locations to represent each crash. Some states use analytical tools to assist with obtaining, processing, and visualizing crash data in order to develop the crash diagrams. **Figure 2** shows an example of a collision diagram. In this image, the different symbols represent different crash types (e.g., rear-end, angle), which provide the analyst an understanding of common safety issues in the area. For example, **Figure 2** shows rear-end crashes near an access point to residential apartment buildings, and this information may warrant a closer examination of the roadway at and around this area to determine potential contributing factors and the need to consider safety improvements.

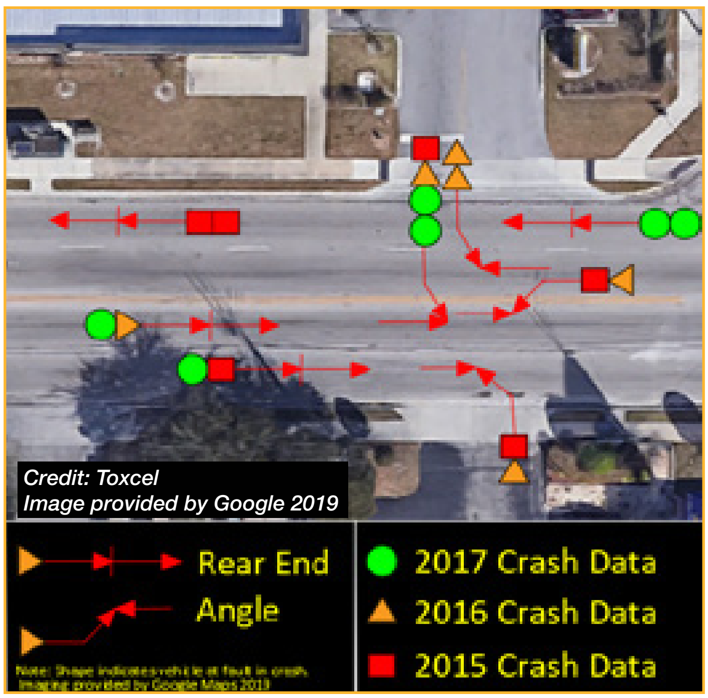


Figure 2: Example Collision Diagram

After completion of the crash data visualization, the analyst will summarize the existing safety issues. This portion of the analysis will include crash pattern summaries that typically are presented in tabular or graphical format. **Figure 3** and **Figure 4** illustrate examples of graphs that show crashes by type and by time-of-day at a specified location. These graphs provide an easy and straightforward way to visualize the existing crash conditions.

Analysts can also identify existing safety issues by performing a site visit, or a more in-depth road safety audit (RSA). A RSA is a formal safety performance evaluation that qualitatively estimates and reports on the potential road safety issues. RSAs can also identify opportunities for improvement, which can aid the analyst in developing alternatives to evaluate later in the TIA process.

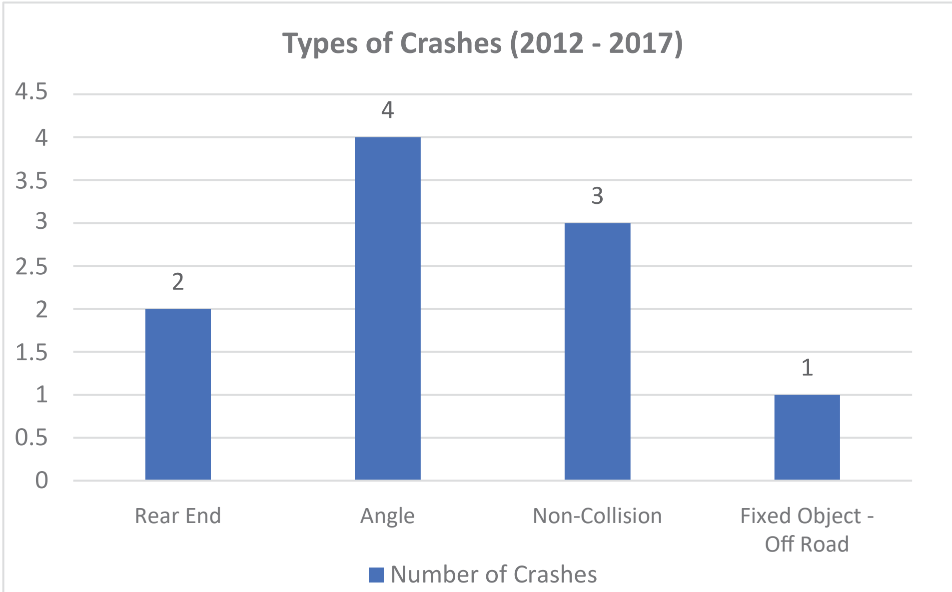


Figure 3: Crashes by Type

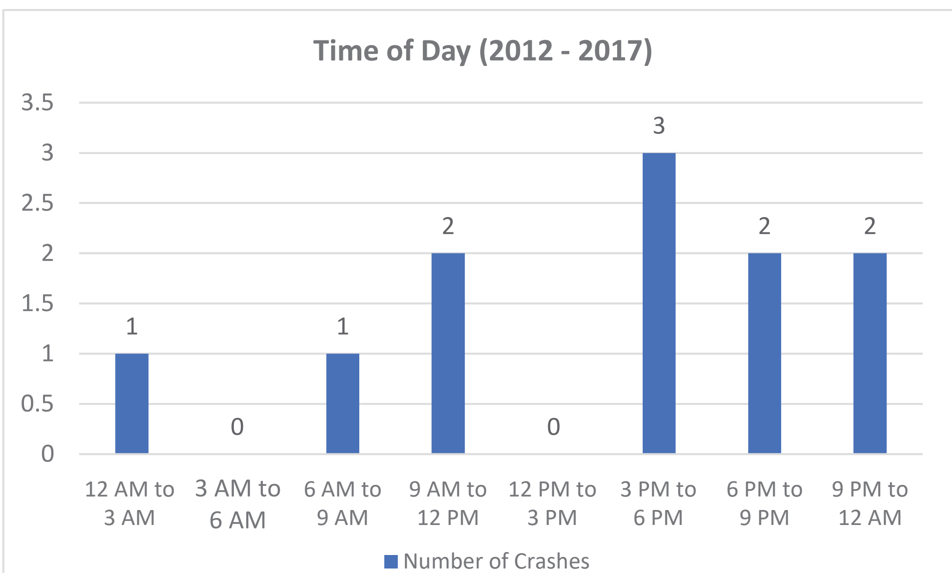


Figure 4: Crashes by Time of Day

Analysis

Action Item: Develop Preliminary Alternatives

Typically, TIAs will evaluate existing conditions such as volume data, geometric features, and configurations and will use this data to prepare preliminary alternatives for roadways and intersections impacted by the development. The alternatives should consider both operational and safety performance as a result of the development. The issues identified in the crash data visualization action item above, in combination with the existing operational factors, can help the analyst prepare fine-tuned alternatives that improve intersection performance from both an operational and safety standpoint. For example, an intersection approach could currently be experiencing a large number of rear-end crashes in a shared left-thru lane. This approach also experiences severe delay due to the large number of drivers waiting to make the left-turn movement. An alternative that recommends the installation of an additional left-turn lane could not only reduce delay, but also reduce the number of rear-end crashes at the intersection. Although the preliminary alternatives should be developed based on the issues present at the intersection or roadway, safety and capacity/operations analysis of these alternatives will be evaluated for the future conditions in future steps of the TIA process.

Action Item: Perform Safety Analysis of Each Preliminary Alternative

Following the analyst's evaluation of the future build and no-build scenarios from an operational perspective, safety analyses will then be conducted to determine the safety performance of each scenario. One method for evaluating safety impacts is the application of Crash Modification Factors (CMFs), which is the value assigned to a certain specific countermeasure to estimate the number of expected crashes following implementation. Another method involves conducting safety analysis using the HSM predictive method. Depending on the complexity of the TIA and the data available, some methodologies would be more beneficial than others, and some may be used concurrently. TIAs with detailed design concepts and available data should be evaluated using the HSM Part C predictive method. The HSM predictive method uses safety performance functions to estimate future crash frequencies using various parameters (e.g., AADT, roadway configurations, and existing crash data). The following section outlines these methods.

HSM Part C Predictive Method

The preferred method to evaluate safety benefits is by conducting a predictive analysis. The HSM provides analysts with a predictive method for estimating crash frequency at specific sites. This method, described in Part C of the HSM, uses safety performance functions (SPFs) – along with CMFs and calibration factors – to estimate the crash frequency of sites based on various characteristics (e.g., roadway characteristics, roadway/intersection geometry, area characteristics). Using the predictive method provides an analyst with an effective and data-driven approach to determining future crash frequency based on the conditions of the roadway.

While the HSM provides equations for analysts to manually estimate crash frequency based on characteristics of the roadways, intersections, or freeways, there are many tools that implement HSM's predictive method in an automated format. This includes several Microsoft Excel-based spreadsheets as well as software developed under NCHRP projects or FHWA.[1] Specifically, FHWA developed two tools to conduct predictive method analysis at the site-specific, project level: The Safety Performance of Intersection Control Evaluation (SPICE) and the Interactive Highway Safety Design Model (IHSDM). Both tools are user-friendly applications which help predict safety performance (crash frequencies and severities) for a site or set of sites (e.g., a section of highway, an intersection) and can be used in complex or relatively simple safety analyses. Each of these tools is described below. It is critical to note that, while both tools provide users with default SPFs and calibration factors, many states have also developed their own for use with HSM models. These local values should be used when appropriate.

1 *American Association of State Highway and Transportation Officials. (2019). Highway Safety Manual - Tool Descriptions. Retrieved from http://www.highwaysafetymanual.org/Pages/tools_sub.aspx#4*

SPICE Tool

The SPICE tool is a Microsoft Excel-based macro workbook that can perform the predictive safety analysis of various types of intersections with readily or limited available data-inputs. With this tool, analysts can assess safety performance while considering performance metrics such as quality of operational service, construction maintenance costs, project context, and other factors. This tool prompts users for basic inputs, automating many of the decisions required for selecting the appropriate SPF or CMF to apply. Based on the input parameters, the tool outputs the predicted or expected crash frequency and crash severity for each alternative, allowing for easy comparison.

IHSDM

IHSDM is a standalone desktop application which provides estimates of expected safety and operational performance based on user-provided highway and intersection designs. This tool prompts users for various data inputs (e.g., number and widths of lanes, intersection control, traffic volume, and historical crash data) and can output predicted or expected crash frequencies.

HSM Part D CMF Application

One method to quickly estimate the safety impacts of changes to transportation infrastructure is the use of CMFs. A useful source for CMFs is FHWA's CMF Clearinghouse,[2] which also includes information on using CMFs. The CMF method is also documented in Part D of the Highway Safety Manual.

Analysts can use **Equation 1** to estimate the number of crashes after a roadway modification is made.

$$C_{estimate} = C_{existing} * CMF \tag{1}$$

Where:

Cestimate= the estimated crash frequency (crashes per year) after the roadway modification

Cexisting= the crash frequency before the roadway modification (crashes per year)

CMF= the crash modification factor

Equation 1 can also be used with multiple CMFs, as shown below.

$$C_{estimate} = C_{existing} * CMF_1 * CMF_2 * CMF_n$$

Where: CMF_n = *the crash modification factor associated with countermeasure n*

2 *Federal Highway Administration. (2018). Crash Modification Factors Clearinghouse. Retrieved from http://www.cmfclearinghouse.org/*

Action Item: Compare Alternatives and Make a Recommendation

Traditionally, recommendations for roadways or intersections were made based on the operational performance and costs of improvements, and often failed to consider safety impacts. Now, recommendations can be made based on operational, safety, and cost considerations.

The analysts can select the most optimal alternative by performing a benefit-cost analysis. This analysis compares all of the benefits (e.g., crash reduction) associated with countermeasures as compared to the cost of implementing the countermeasure, in the form of a ratio (benefit/cost). These analyses allow the developer and agency to quantify impacts in a monetary form as a way of easily comparing the cost and safety benefits offered in each alternative. Additionally, analysts can also conduct an incremental benefit-cost analysis, which produces a ranking of different projects to determine which project is the best economic investment. Two sources that are currently available to assist with the implementation of benefit-cost analyses are FHWA's Highway Safety Benefit Cost Analysis Guide and tool.[3]

Analysts can also perform a high-level comparison of alternatives using the crash prediction values generated by the SPICE tool. Depending on the analysis selected, the predicted total and fatal-injury crash frequencies are displayed for the opening year, design year, and the total project life cycle. The analyst can then feed these values into the BCA tool to compare the alternatives Analysts can also perform a similar comparison using the Economic Analysis module built into the IHSDM. Both of these tools can help analysts compare the alternatives with respect to benefits and costs.

Analysts conducting these analyses will be faced with difficult decisions as they make recommendations to the agency, and thus should exercise engineering judgment in making recommendations. For example, it can be difficult for analysts to recommend one alternative that has slightly better safety outputs with considerably higher construction costs versus a more cost-effective alternative that has fewer safety benefits (i.e., crash reduction). While states and agencies may have varying policies on how to evaluate and properly select alternatives, they should serve to evaluate whether the proposed improvements satisfy the project goals, meet the needs of motorized and non-motorized users, and whether they benefit both the community and stakeholders.

Other Considerations

In addition to the crash analysis described above, the analyst should consider other safety-related elements when completing a TIA.[4] Analysts should review the proposed plans to determine if:

- *The necessary access points are available for the project.*
- *The existing and proposed access points are sufficiently spaced to reduce the risk of conflicts.*
- *Traffic control or geometric design is needed to restrict left turns.*
- *There are opportunities to consolidate the number of access points (e.g., shared driveway).*
- *Sight distance is adequate for all new and modified facilities.*
- *Adequate pedestrian and bicyclist facilities exist in the proposed plan.*
- *Considerations for commercial vehicle traffic are included.*
- *Adjacent transit points exist along the adjacent roadway(s) and how the proposed development could impact the use of these transit points.*

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3 Federal Highway Administration. (2019). Highway Safety Improvement Program (HSIP) – Planning. Retrieved from https://safety.fhwa.dot.gov/hsip/planning.cfm

4 McRae, J., Bloomberg, L., & Muldoon, D. (2006). Best Practices for Traffic Impact Studies (Final Report No. FHWA OR-RD-06-15). Salem, OR. Retrieved from https://www.oregon.gov/ODOT/Programs/ResearchDocuments/BestPracticesforTraffic.pdf

Overcoming Potential Challenges

This section discusses some of the possible challenges faced when integrating safety into TIAs and how to overcome those challenges.

Operational Analysis vs. Safety Analysis

While operational and safety analyses aim to support each other, many TIAs prioritize operational benefits, with safety benefits being secondary. Often, safety considerations are only included in a TIA when they are convenient or are required by the local agency, and even then, these considerations are not truly integrated into the design process. From the operational perspective, design elements are typically evaluated using periods of peak demand. It is important to realize that what is operationally better for peak-period operations is not necessarily what is best for safety under the full range of conditions. Integrating DDSA into a TIA can help the analyst understand how different proposed designs will function from separate operational and safety standpoints, leading to a recommendation that then jointly considers both of these inputs.

Difficulty Comparing Proposed Improvements

Different roadway improvements will affect safety differently. For example, it may seem difficult to compare an improvement that reduces a large number of minor crashes with one that reduces a small number of more severe crashes, but researchers and analysts have developed costs that help do just that.[5] Crash costs, often defined by the crash severity and crash type, allow analysts to summarize the safety impacts of roadway improvements in a way that allows simple comparisons. Further, defining safety impacts as a monetary value not only allows the analyst to compare safety impacts to each other, it allows the analyst to compare these impacts to roadway improvement cost and show the ratio of costs to benefits for the roadway improvement.

The Credibility of the Safety Analyses

Data-driven safety analysis builds on decades of research and collaboration by AASHTO, TRB, and FHWA. In 2016, FHWA published a series of five informational guides on the Reliability of Safety Management Methods, which demonstrated the value of the more reliable (predictive) methods highlighted in this how-to guide over traditional methods. These methods allow the safety analysis to have a quantitative foundation, which allows the results of these analyses to be just as compelling as the results of operational analyses. Additionally, to further improve the confidence in safety analyses performed using CMFs, the CMF Clearinghouse provides a quality rating of each CMF to help analysts select those CMFs that have been developed through the most thorough analyses. It is recommended to check with the state and local transportation agencies about their guidelines for the application of CMFs in a safety analysis; some agencies provide guidelines on the minimum required quality level for CMFs or have a state-preferred CMF list.

Level of Effort Required to Complete a Safety Analysis

One reason transportation agencies and consultants often leave safety analyses out of TIAs is that they assume that completing such analyses requires a significant level of effort. However, as discussed in this guide, safety analyses can be completed without expending a substantial level of effort and will add value to the resulting TIA. With the use of GIS and online mapping tools, an analyst can review locations for existing conditions of an intersection or roadway, and supplement this with feedback from local authorities about their knowledge of existing operational and safety conditions. Additionally, FHWA also makes other tools available (e.g., SPICE, IHSDM) to facilitate a predictive safety analysis. FHWA has developed these tools to use data-driven procedures supported by existing transportation safety research. Using simple and available resources, analysts can conduct safety analyses that will provide insight for recommendations that will benefit the site from both operational and safety considerations.

5 Harmon, T., Bahar, G., & Gross, F. (2018). Crash Costs for Highway Safety Analysis (Final Report No. FHWA-SA-17-071). Washington, DC. Retrieved from https://safety.fhwa.dot.gov/hsip/docs/fhwasa17071.pdf

Example: Traffic Impact Analysis (TIA) with Data-Driven Safety Analysis Integration

The following section provides an example of how to integrate DDSA into the TIA procedure. The TIA example follows a proposed new development (a pharmacy) on the corner of a signalized intersection within a moderately developed area. The example describes the typical process for a TIA, but also includes the ***DDSA action items*** as part of the procedure.

Figure 5: Proposed Development Location

Project Overview

Company X is proposing to develop a pharmacy with a drive-through on the northwest corner of Smith Road and Main Street, shown in **Figure 5**. The area proposed for development is currently vacant and is primarily bound to the northeast and south by commercial developments, with residential dwellings located to the west. The proposed development plan consists of a 12,000 square foot development which includes a drive-through. The site can be accessed via the west leg of the existing traffic signal of Main Street at Smith Road. The development is being proposed across the street from a large existing residential development, and currently the intersection has no pedestrian facilities. The project is expected to be completed and opened by the year 2020.

Existing Conditions and Projected Growth

Site Development Traffic Forecasting

The analyst performed trip generation calculations for the proposed development using the Institute of Transportation Engineer's (ITE) Trip Generation report, 9th Edition. The analysis used ITE Land Use Code (LUC) 881: Pharmacy/Drugstore with Drive-Through Window.

Based on the trip generation evaluation, the proposed development is expected to generate 46 gross new AM peak hour trips (24 entering trips, 22 exiting trips) and 123 gross new PM peak hour trips (62 entering trips, 61 exiting trips). A pass-by rate of 49 percent (49.0%) was applied based on ITE Trip Generation Handbook, generating 23 net new AM peak hour trips (12 entering trips, 11 exiting trips) and 63 net new PM peak hour trips (32 entering trips, 31 exiting trips). **Table 1** indicates the breakdown of the trip generation.

Table 1: Trip Generation Calculations

Trip Generation Calculation for AM and PM peak hour trips			
Proposed Development	**Gross Trips**	**Pass-By Capture**	**Net New Trips**
Pharmacy with Drive-Through	46 (24 in/22 out)	49.0%	23 (12 in/11 out)
	123 (62 in/61 out)		*63 (32 in/31 out)*
AM peak hour; *PM peak hour*			

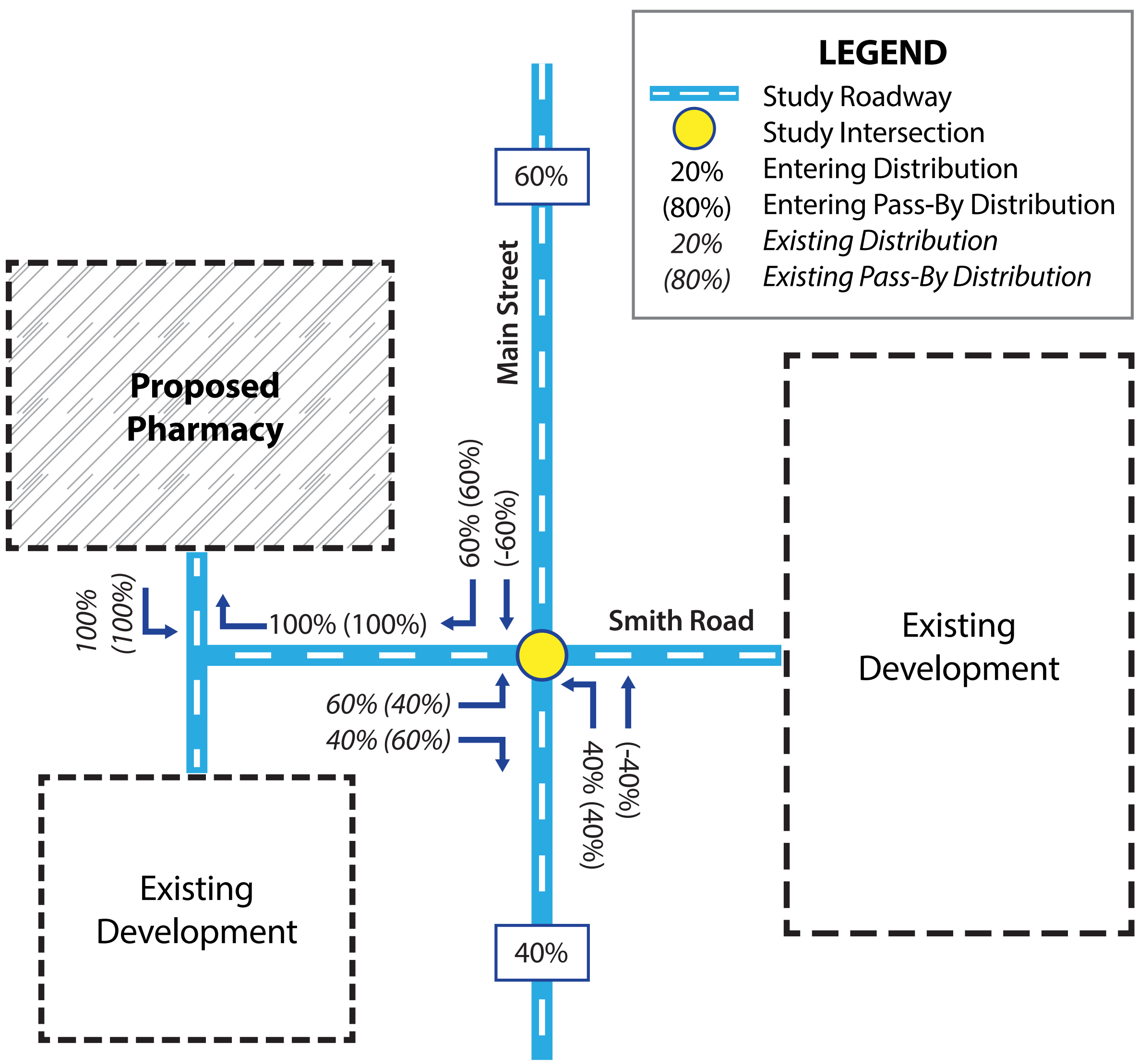
Credit: Fotosearch

Volume Forecasting

The analyst collected existing condition turning movement counts for the intersection on a typical weekday in 15-minute intervals. Based on the existing traffic volume data, the PM peak hour volumes were used for the analysis, as the development is expected to generate higher volumes during the PM peak hour. Traffic growth was projected to 2020, the proposed build-out date, by applying a historic growth rate to existing 2018 traffic volumes. The analyst determined this growth rate based on historical growth trends along the Main Street corridor. The three sets of data used for the analysis were:

- *Existing Conditions (2018 volumes no-build)*
- *Future Background Conditions (2020 volumes no-build)*
- *Future Total Conditions (2020 volumes build)*

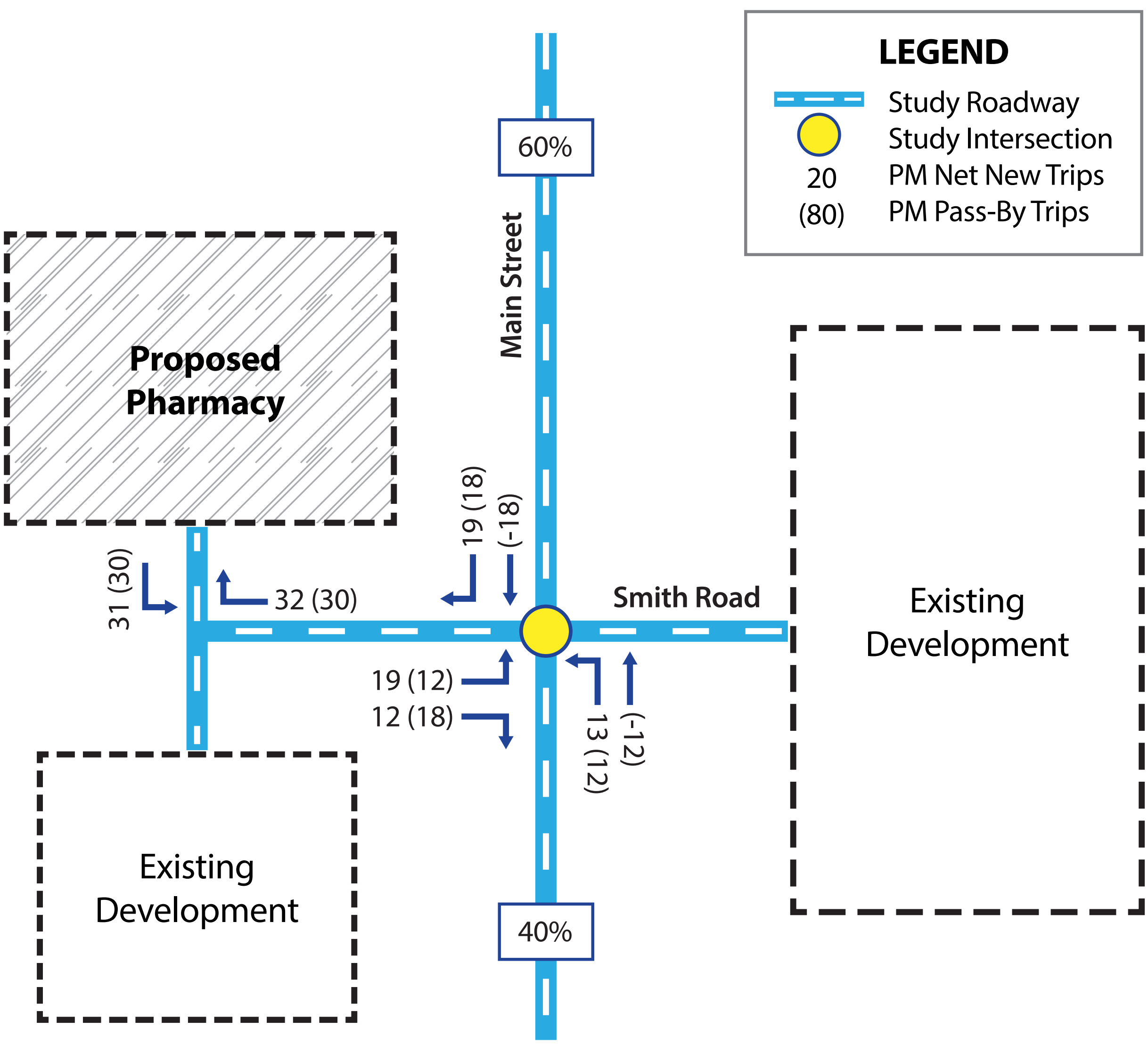
Figure 6: Trip and Pass by Distribution



The analyst generated future total traffic by taking the Future Background conditions (2020 volumes no-build) and adding in the project traffic (i.e., net new trips + pass-by trips) to the intersection.

Figure 6 and Figure 7 illustrate the expected project distribution, pass-by distribution, and driveway volumes, based on the proposed development. For purposes of this traffic impact analysis example, the PM peak hour will be the only peak evaluated based on net new trips generated and the existing turning movement counts.

Figure 7: Trip and Pass by Assignment



Pedestrian Volumes

Along with vehicular volumes, the analyst also collected pedestrian volumes for the intersection on a typical weekday in 15-minute intervals. The AM and PM peak period pedestrian counts are shown in **Table 2**.

Table 2: Peak Period Pedestrian Counts

Intersection Leg	AM Peak Period	PM Peak Period
North	10	13
South	9	11
East	13	16
West	11	12

The analyst also projected pedestrian volumes to 2020 to evaluate future pedestrian needs for the build alternatives.

Visualize Crash Data and Identify Safety Issues

The analyst reviewed existing crash data and performed a site visit for the intersection of Smith Road and Main Street to determine crash patterns. Based on the review of the most recent three years of data, illustrated in **Figure 8** and **Figure 9**, the analyst documented the following patterns and observations:

- *22 crashes (17 PDO; 5 FI) occurred at the intersection over the most recent three years (2015-2017), equating to 7.3 crashes per year (5.7 - PDO; 1.7 FI).*
- *Rear-end crashes are the most prominent crashes (37% of crashes), followed by sideswipe crashes (27% of crashes). Rear-end crashes are typically the most common crashes at signalized intersections.*
- *Observations at the intersection indicated that no retroreflective backplates exist on the signal heads. There are signal heads for every lane in both the northbound and the southbound approaches. There are also signal heads present for the eastbound and westbound approaches. All traffic signal lenses are LED and 12 inches in diameter.*
- *The eastbound and westbound left-turn movements are currently permissive only. Right turns on red were allowed.*
- *No pedestrian facilities are provided at the intersection, and no sidewalks are located along the north and south legs of the intersection. However, pedestrians were observed crossing all four legs of the study intersection (see Table 2) and several pedestrian generators are located nearby.*
- *No pedestrian related crashes occurred at the intersection over the three-year period.*
- *Overhead lighting is not present at the intersection, but there is existing commercial and corridor lighting surrounding the intersection.*

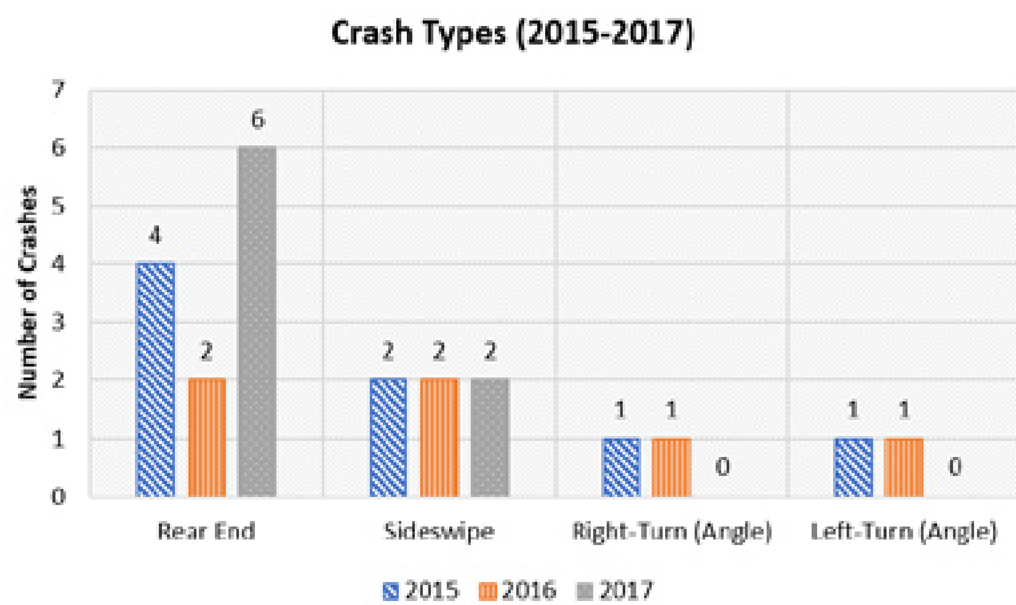


Figure 8: Crashes by Type (2015-2017)

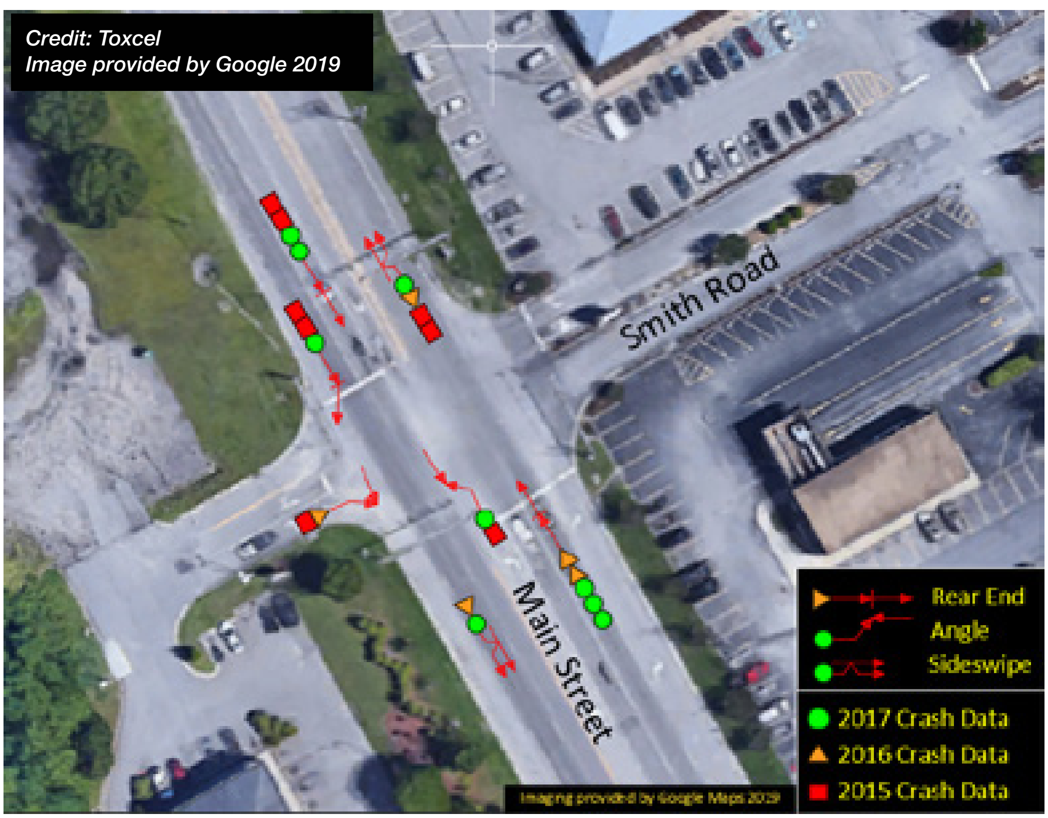


Figure 9: Collision Diagram (2015-2017)

The crash data correlations and safety observations summarized here will provide a basis for the proposed development to consider including safety treatments and strategies, as part of the overall improvements, that can target these issues and enhance the safety performance of the intersection.

Existing Operational/Queueing Analyses

The analyst evaluated operating and queuing conditions for the impacted intersection of Main Street at Smith Road for the existing conditions based on Highway Capacity Manual 6th Edition. **Table 3** shows results of the capacity analysis for the existing intersection.

Table 3: Intersection Capacity Analysis (Existing Conditions)

Year 2018 Delay (LOS)	**Existing Conditions**				
Peak Hour	EB	WB	NB	SB	Overall
AM Peak Hour – Average Control Delay in Seconds/ Vehicle (LOS)	48.9 (D)	52.9 (D)	5.0 (A)	4.9 (A)	7.4 (A)
PM Peak Hour – Average Control Delay in Seconds/ Vehicle (LOS)	35.6 (D)	54.9 (D)	13.6 (B)	13.4 (B)	16.7 (B)

Based on the capacity analysis, the intersection overall operates acceptably at LOS B or better. However, the EB and WB approaches operate at LOS D during both peak hours. Based on the 95^{th} percentile queuing analysis, all vehicles are expected to be accommodated within the existing turn-bay storage lengths.

Future No-Build Analysis

The analyst used the projected volumes to evaluate operating and queuing conditions for the future no-build scenario. The future no-build scenario, also known as the future background, includes changes in volume due to growth, but does not changes in volume resulting from a new development. **Table 4** shows the results of the capacity analysis for the intersection.

Table 4: Intersection Capacity Analysis (Future Background)

Year 2020 Delay (LOS)	**No-Build Conditions**				
Peak Hour	EB	WB	NB	SB	Overall
AM Peak Hour – Average Control Delay in Seconds/ Vehicle (LOS)	47.3 (D)	52.4 (D)	5.7 (A)	5.5 (A)	8.0 (C)
PM Peak Hour – Average Control Delay in Seconds/ Vehicle (LOS)	35.5 (D)	60.9 (E)	14.1 (B)	14.0 (B)	17.6 (B)

Based on the capacity analysis, the overall intersection operates at LOS C or better during both peak periods. The amount of delay experienced by the eastbound and westbound approaches increased, but both approaches still operate at LOS E in the westbound direction during the PM peak.

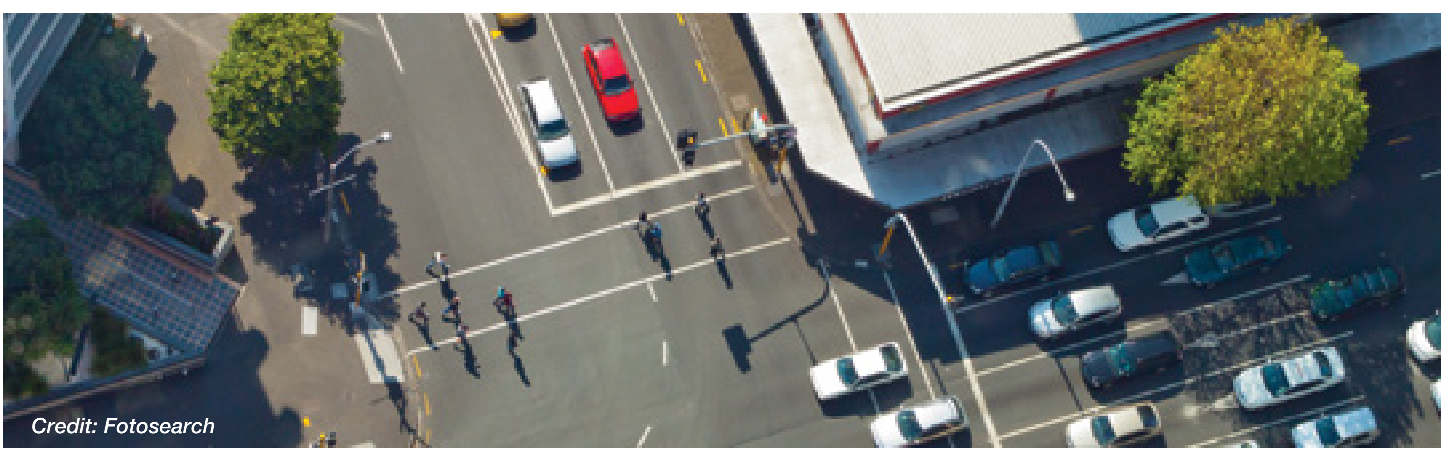
Analysis

Develop Preliminary Alternatives

Based on the results of the existing conditions and projected growth, the following alternatives are proposed:

- *Alternative 1:*
    - *Installation of retroreflective backplates on signal heads.*
    - *Installation of pedestrian facilities (e.g., curb ramps and tactile domes, striped crosswalk, and pedestrian signals) across the north and south legs of the intersection.*
    - *Optimized signal timings.*
- *Alternative 2:*
    - *Installation of retroreflective backplates on signal heads.*
    - *Installation of pedestrian facilities (e.g., curb ramps and tactile domes, striped crosswalk, and pedestrian signals) across the north and south legs of the intersection.*
    - *Optimized signal timings.*
    - *Installing a southbound-right turn lane.*
    - *Lane geometry conversion of eastbound and westbound approaches from shared left/through lane + right lane to left lane + shared through/right lane, which allows phasing change from permitted to protected-permitted.*

Based on the review of the improvements, the installation of the retroreflective backplates on signal heads should serve to improve the visibility of signal heads, and is proven to help reduce crashes, specifically rear-end crashes. Despite the lack of facilities, several pedestrians were recorded crossing at the intersection during both peak periods. The installation of pedestrian facilities will help connect non-motorized users between the developments and will serve as a control crossing point for non-motorized users. Additionally, optimizing the signals has proven crash reduction results while improving overall operations of the intersection. Alternative 2 not only incorporates the changes proposed for Alternative 1, but also includes additional geometric improvements. The installation of the dedicated right-turn lane will serve to accommodate the new increase in southbound right-turning traffic because of the proposed pharmacy. The conversion of the lane geometry and phasing on the eastbound and westbound approaches will help to provide greater and safer throughput for left-turning movements (i.e., highest movements in future conditions), and will help to accommodate safer conditions for the proposed pedestrian crossings.


Credit: Fotosearch

Operational Analysis

The analyst evaluated operating and queuing conditions for the impacted intersection of Main Street at Smith Road for existing, future background and future total conditions were developed based on Highway Capacity Manual 6th Edition for Alternative 1 and Alternative 2. **Table 5** describes the results of the capacity analysis for Alternative 1 and Alternative 2.

Table 5: Alternative 1 and 2 Intersection Capacity Analysis (2020 Total Conditions)

Year 2020 Delay (LOS)	Alternative 1					Alternative 2				
Peak Hour	EB	WB	NB	SB	Overall	EB	WB	NB	SB	Overall
AM Peak Hour – Average Control Delay in Seconds/Vehicle (LOS)	45.1 (D)	48.6 (D)	8.2 (A)	8.5 (A)	10.9 (B)	62.2 (E)	56.5 (E)	4.0 (A)	4.0 (A)	7.8 (A)
PM Peak Hour – Average Control Delay in Seconds/Vehicle (LOS)	56.0 (E)	50.2 (D)	18.1 (B)	19.5 (B)	23.0 (C)	58.6 (E)	57.0 (E)	5.5 (A)	5.6 (A)	12.0 (B)

Based on the results of the capacity analyses, Alternative 2 performs slightly better than Alternative 1, likely due to the additional capacity in the southbound approach and the reconfiguration of the minor street approaches.

Safety Analysis and Comparison

Following the completion of the operational analyses, the analyst evaluated the safety benefits of both proposed alternatives using IHSDM and the CMF Clearinghouse to calculate the associated safety benefits. CMFs were applied separately in order to estimate the safety benefits associated with the installation of retroreflective backplates and the installation of pedestrian facilities, which cannot be quantified in IHSDM.

Predictive Method

The analyst used IHSDM to perform the HSM Part C predictive method and determine the expected crash frequency of the intersection for Future – No Site Traffic – No Build, Future – Site Traffic – No Build, Alternative 1, and Alternative 2 **(Table 6)**.

Table 6: 20-Year Crash Frequency Results (IHSDM)

Alternative	2020 through 2040 Total Crash Frequency
Future – No Site Traffic – No Build	112.3 (84.58 – PDO; 27.72 – FI)
Future – Site Traffic – No Build*	129.91 (98.21 – PDO; 31.70 – FI)
Future – Site Traffic – Alternative 1*	129.91 (98.21 – PDO; 31.70 – FI)
Future – Site Traffic – Alternative 2	119.66 (91.31 – PDO; 28.35 – FI)

**Future – Site Traffic - No-Build and Future – Site Traffic – Alternative 1 are expected to have the same total crash frequency because neither option includes geometric changes. The crash frequency for Alternative 1 will change after the application of CMFs, which is shown below.*

CMF Application

Improvements that could not be evaluated within IHSDM were analyzed by applying CMFs separately to the results obtained from IHSDM. CMFs from the CMF Clearinghouse were selected and applied to crash frequencies provided by IHSDM. **Table 7** illustrates the specific improvements selected and their respective CMF values. In some cases, CMFs may exist for an improvement, but those CMFs may not be applied in the analysis. For example, the "install high-visibility crosswalk" is an appropriate CMF for the "installation of a crosswalk" improvement. However, some states may require a certain CMF quality rating for the analysis. In this example, a three-star rating was the lowest acceptable and the "installation for crosswalk" improvement has a quality rating of two stars. Therefore, the CMF for "install high-visibility crosswalk" was not used. As a second example, a CMF for "optimizing signals" does not exist in the CMF Clearinghouse and thus this improvement cannot be accounted for in the analysis.

Table 7: Proposed Intersection Modifications and CMFs

Countermeasure	CMF Description	CMF ID & CMF Value	Clearinghouse Quality Level	Crash Applicability Description	Included In the Analysis?
Installation of crosswalk	"Install High-Visibility Crosswalk"	CMF ID: 4123 0.60	2 stars	Vehicle/Pedestrian Crashes	No
Install pedestrian countdown timer	"Install Pedestrian Countdown Timer"	CMF ID: 8790 0.912	3 stars	All crashes at the inter-section	Yes
Add retroreflective backplates	"3-inch yellow retro-reflective sheeting to signal backplates"	CMF ID: 1410 0.85	4 stars	All crashes at the inter-section	Yes
Optimize Signals	CMF does not exist	N/A	N/A	N/A	No

Applicable Crash Calculations

Based on the crash applicability description (**Table 7**), crash reduction factors of 0.912 (installing pedestrian countdown timer) and 0.85 (installation of retroreflective backplates) were applied to all crashes. Because both CMFs can be applied to all crashes, a composite CMF was calculated as outlined in the HSM. **Table 8** represents the combined CMF for both installing pedestrian signals and installing retroreflective backplates.

Table 8: Composite CMF and Applicable Crashes

Countermeasure	Crash Modification Factor	Applicable Crash Percentage
Install pedestrian countdown timer + install retroreflective backplates	0.78[1]	100% of crashes

[1] Composite CMF was calculated by multiplying 0.912 and 0.85 crash modification factors for installing pedestrian countdown timer and adding retroreflective backplates, respectively.

Safety Performance Evaluation

The CMFs are then applied to the results of the predictive method to determine the finalized crash reduction over the anticipated 20-year service life. **Table 9** indicates the crash reductions resulting from the application of the two CMFs. The equations below illustrates the calculation for determining the total crash frequencies and total crash reduction percentages for each alternative.

Table 9: Crash Reduction Results with Predictive Method and CMF Application

Alternative	20-Year IHSDM Crash Frequency (From Table 7)	Composite Crash Modification Factor	Applicable Crashes (%)	Total Crash Frequency with CMF (20 Years)	Total Crash Reduction (Count, 20 Years)	Total Crash Reduction (Percentage, 20 Years)
Future – Site Traffic - No-Build	129.91 (98.21 – PDO; 31.70 – FI)	N/A	N/A	N/A	N/A	0%
Future – Site Traffic - Alternative 1	129.91 (98.21 – PDO; 31.70 – FI)	0.78	100%	101.3 (76.6 – PDO; 24.7 – FI)	28.6 (21.6 – PDO; 7.0 – FI)	22.0%
Future – Site Traffic - Alternative 2	119.66 (91.31 – PDO; 28.35 – FI)	0.78	100%	93.3 (71.2 – PDO; 22.1 – FI)	36.6 (27.0 – PDO; 9.6 – FI)	28.2%

$$\textit{Alternative Crash Frequency} = (\textit{Alternative IHSDM Crash Frequency}) * (\textit{CMF}) * (\textit{Percentage of Applicable Crashes})$$

$$\textbf{Alternative 1}\ \textit{Total Crash Frequency} = 129.91 * 0.78 * 100\%$$

$$\textit{Total Crash Reduction Percentage} = \left(\frac{\textit{Alternative Crash Frequency - No Build Crash Frequency}}{\textit{No Build Crash Frequency}}\right)$$

$$\textbf{Alternative 1}\ \textit{Total Crash Reduction Percentage} = \left(\frac{101.3 - 129.9}{129.9}\right) * 100\%$$

Based on the safety analysis, **22.0%** and **28.2%** total crash reduction percentages are expected for Alternatives 1 and 2, respectively.

Benefit-Cost Analysis

The analyst conducted a benefit-cost analysis to quantify the impacts of each alternative. A severity-weighted crash cost was developed for fatal and injury crashes using three years of crash data and the costs shown in **Table 10**.[6] The severity-weighted crash cost was calculated to be $446,212 (2016 dollars). The crash cost used for property damage only crashes was $11,900 (2016 dollars).

Table 10: Comprehensive Crash-Level Costs

Severity	Comprehensive Crash-Level Cost (2016 dollars)
K	$11,295,400
A	$655,000
B	$198,500
C	$125,600
O	$11,900

The present value of the cost savings due to the reduction in crashes was found for each alternative using a seven percent discount rate, and benefit-cost ratios were calculated (**Table 11**).

Table 11: Benefit-Cost Analysis Comparing Alternative 1 and Alternative 2 to the Future No-Build alternative

Alternative	Total Crash Reduction Difference	Present Value of Crash Cost Savings (20 Years)	Total Estimated Costs	Benefit-Cost Ratio
Alternative 1	28.6 (21.6 – PDO; 7.0 – FI)	$2,015,410	$115,000	17.5
Alternative 2	36.6 (27.0 – PDO; 9.6 – FI)	$2,745,382	$150,000	18.3

Preferred Alternative

The present value of the crash cost savings was found to be $2,015,410 and $2,745,382 over the course of the 20-year period resulting in benefit-cost ratios of 17.5 and 18.3 for Alternatives 1 and 2, respectively. Based on the results of the benefit-cost analysis and the operational analysis, the analyst recommended implementing Alternative 2 given the greater benefit-cost ratio and improved operations.

6 Harmon, T., Bahar, G., & Gross, F. (2018). Crash Costs for Highway Safety Analysis (Final Report No. FHWA-SA-17-071). Washington, DC. Retrieved from https://safety.fhwa.dot.gov/hsip/docs/fhwasa17071.pdf

Key Findings

This analysis addressed the traffic-related impacts associated with the proposed 12,000 square foot pharmacy on the northwest corner of the Main Street and Smith Road. The following conclusions are based on the conducted typical capacity and safety analyses:

- *The project is expected to generate 23 net new AM peak hour trips and 63 net new PM peak hour trips. The corresponding peak pedestrian counts at the intersection are 43 in the AM peak hour and 52 in the PM peak hour.*
- *The existing intersection has 22 crashes over the most recent three years (2015-2017), with rear-end crashes (37%) being the most common type. Patterns of crashes showed a high presence of rear-end crashes on the northbound and southbound approaches.*
- *Intersection capacity analyses indicate that the study intersection of Main Street and Smith Road is expected to operate at a LOS C or better during the PM peak hour for the intersection overall in each scenario.*
- *Results of the 95th percentile queuing analysis indicate, under future build total conditions, that existing lane configurations are expected to be accommodated within provided storage lengths.*
- *Based on the results of the benefit-cost analysis, Alternate 2 was recommended as the preferred alternative. Alternative 2 includes adding a southbound right turn lane, reconfiguring the lanes on the eastbound and westbound approaches, the addition of pedestrian facilities at the intersection, signal optimization, and enhancing signal conspicuity.*
- *An overall crash reduction of 28.2% is expected for the preferred alternative. A total savings of approximately $2,745,382 is expected over the course of the 20-year period resulting in a benefit-cost ratio of 18.3 for the preferred alternative.*

Conclusion

New developments often can be controversial. Communities believe there will be an increase in traffic and disruptions to the existing road network as a result of the development. However, including safety analysis and providing recommendations that will benefit both non-motorized and motorized users could help influence the local community view of the project and could make the approval process more manageable for the developer. Additionally, without a safety analysis, a TIA does not properly identify the true impacts of a proposed development. A safety analysis can provide value to the public by identifying potential safety issues imposed on roadways and intersections from the new development. Basic DDSA techniques can be integrated into the development of TIAs by analysts without expending a significant level of effort.