Indiana Department of Transportation

Indiana's State Road 37 Improvement Project

SAFETY DATA CASE STUDY

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16. Abstract This case study presents an interchange alternatives analysis from the Indiana Department of Transportation (INDOT). The analysis supported a multi-agency planning and engineering effort that involved INDOT, the Indianapolis Metropolitan Planning Organization, Hamilton County, Town of Fishers, and City of Noblesville. These agencies identified State Road (SR) 37 from 126th Street in Fishers to SR 32/38 in Noblesville as a candidate for significant mobility and safety improvements. The SR 37 corridor project had two primary needs: 1) reduce existing and forecasted congestion at signalized intersections within the study area, and 2) reduce the crash frequency and rate at identified intersections. INDOT targeted five, at-grade signalized intersections along the study corridor for interchange improvements. The safety analysis applied State-specific safety performance functions (SPFs) and crash modification factors (CMFs) derived from the American Associate of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (HSM) to predict crashes for "Build" and "No-Build" scenarios over a 20-year period between 2018 and 2038. The INDOT analysis encountered several key challenges, including key technical inputs for the Interactive Highway Safety Design Model (IHSDM) software and the application of the HSM to future design alternatives; for instance, INDOT did not apply the Empirical-Bayes (EB) method due to the significant change in the design and operational performance of the corridor between the Build and No-Build scenarios. INDOT's ingenuity and engineering judgment allowed the agency to navigate many of these challenges, and the analysis predicted that the Build alternative, although originally proposed for its traffic operational improvements, should yield a safety benefit and reduce crashes compared to the No-Build alternative future.		
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Acronyms

Acronym	Description
AADT	annual average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
CMF	crash modification factor
EB	Empirical-Bayes
FHWA	Federal Highway Administration
FI	fatal and injury
HSM	Highway Safety Manual
IHSDM	Interactive Highway Safety Design Model
IN	Indiana
INDOT	Indiana Department of Transportation
LOS	level of service
PDO	property damage only
RoadHAT	Road Hazard Analysis Tool
SPF	safety performance function
SPI	Single Point Interchange
SR	State Road
TOA	traffic operations analysis

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Executive Summary

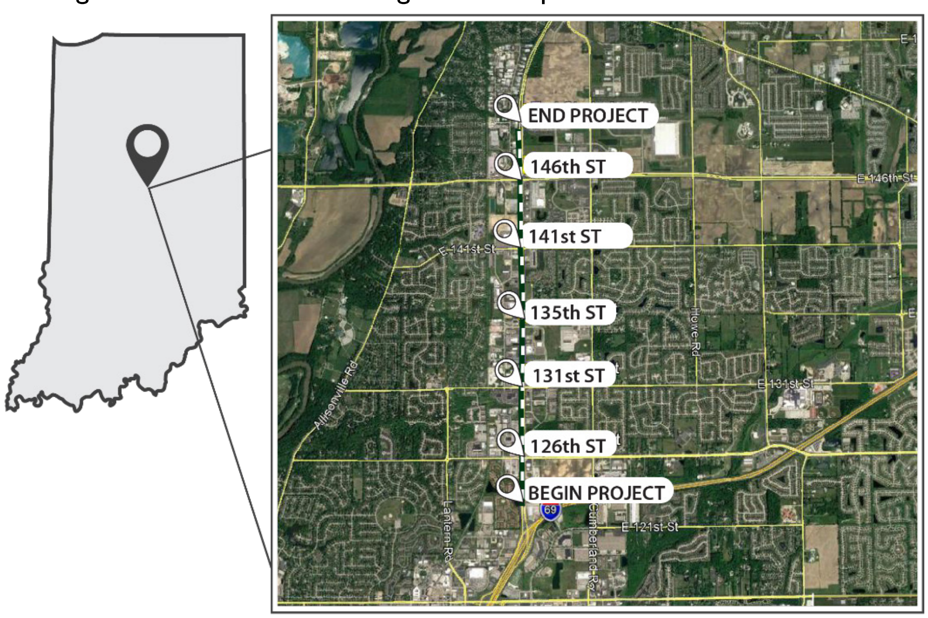
This case study presents an interchange alternatives analysis from the Indiana Department of Transportation (INDOT). The analysis supported a multi-agency planning and engineering effort that involved INDOT, the Indianapolis Metropolitan Planning Organization, Hamilton County, Town of Fishers, and City of Noblesville. These agencies identified State Road (SR) 37 from 126th Street in Fishers to SR 32/38 in Noblesville as a candidate for significant mobility and safety improvements. The SR 37 corridor project had two primary needs: 1) reduce existing and forecasted congestion at signalized intersections within the study area, and 2) reduce the crash frequency and rate at identified intersections. INDOT targeted five, at-grade signalized intersections along the study corridor for interchange improvements. The safety analysis applied State-specific safety performance functions (SPFs) and crash modification factors (CMFs) derived from the American Associate of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (HSM) to predict crashes for "Build" and "No-Build" scenarios over a 20-year period between 2018 and 2038. The INDOT analysis encountered several key challenges, including key technical inputs for the Interactive Highway Safety Design Model (IHSDM) software and the application of the HSM to future design alternatives; for instance, INDOT did not apply the Empirical-Bayes (EB) method due to the significant change in the design and operational performance of the corridor between the Build and No-Build scenarios. INDOT's ingenuity and engineering judgment allowed the agency to navigate many of these challenges, and the analysis predicted that the Build alternative, although originally proposed for its traffic operational improvements, should yield a safety benefit and reduce crashes compared to the No-Build alternative future.

Introduction

The Transportation Research Board's Safety Performance Analysis (ACS20) User Liaison Subcommittee has an on-going initiative focused on practical application of the American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (HSM) (i.e., "using the HSM in the real world"). FHWA also administers the HSM Implementation Pooled Fund, which includes 22 States focused on projects to help further HSM implementation. Development of HSM case studies will assist practitioners in performing data-driven safety analysis using the advanced methods described in the HSM. The primary purpose of the HSM case studies is to highlight noteworthy applications of HSM methods, focus on common challenges, and feature agencies that overcame those challenges. These case studies serve as a source of lessons learned and noteworthy practices to help guide practitioners applying the HSM.

Background

This case study presents an interchange alternatives analysis from the Indiana Department of Transportation (INDOT). The analysis supported a multi-agency planning and engineering effort that involved INDOT, the Indianapolis Metropolitan Planning Organization, Hamilton County, and the cities of Fishers and Noblesville. These agencies identified State Road (SR) 37 from 126th Street in Fishers to SR 32/38 in Noblesville as a candidate for significant mobility and safety improvements (figure 1). The primary improvement was a proposed conversion of an urban arterial street with at-grade intersections to a freeway configuration. As part of this freeway conversion, INDOT prepared a mobility report that considered the operational impacts of a substantial conversion of at-grade signalized intersections to two interchange build alternatives: 1) a teardrop roundabout interchange alternative and 2) a tight diamond interchange alternative with traffic signals at ramp terminals where needed.



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Note: The white location pins and white dashed line were added by the authors to delineate the project bounds.

Figure 1. Graphic. SR 37 project location.

Purpose and Need

The SR 37 corridor project had two primary needs:

1. Reduce existing and forecasted congestion at signalized intersections within the study area.
2. Reduce the crash frequency and rate at identified intersections.

INDOT conducted a traffic operations analysis (TOA) to determine the effect of each alternative on traffic congestion in the base year (2010) and forecast year (2036). The TOA projected that teardrop roundabout interchanges are expected to improve the typical level of service (LOS) at each of the studied intersection legs from a C or D in the base year conditions (2010) to a LOS of A or B in 2036. Based on these results, the multi-agency project steering committee and elected officials decided to pursue teardrop roundabouts as the preferred alternative; this design became the "Build" option. INDOT compared this Build alternative with the existing "No-Build" alternative for safety performance using HSM methods.

Project Description

- **Sponsoring agency:** INDOT.
- **Project location:** Cities of Fishers and Noblesville, IN.
- **Project bounds and length of project:** SR 37 between 126th Street and 146th Street (2.8 miles).
- **Area and Facility type(s):** 4-lane urban, divided arterial (to be converted to a freeway).
- **Area type:** Urban.
- **Project status (summer 2020):** Analysis complete and pending construction.

Safety Performance Analysis

This section provides an overview of the safety analysis methods, proposed alternatives, and final results.

Analysis Overview

INDOT targeted five, at-grade signalized intersections along the study corridor for interchange improvements.

- SR 37 at 126th Street.
- SR 37 at 131st Street.
- SR 37 at 135th Street.
- SR 37 at 141st Street.
- SR 37 at 146th Street.

Before alternative designs could be developed, INDOT performed a preliminary analysis of historic crashes at these five intersections; the agency used an internal tool, the Road Hazard Analysis Tool (RoadHAT), to analyze a recent four-year study period (2010-2013). The RoadHAT tool is a software-based version of the workflow described in INDOT's *Guidelines for Roadway Safety Improvements* (Tarko and Romero, 2016). This document outlines standards for identifying high-crash locations, reviewing these high-crash locations, and evaluating economic impacts of proposed safety projects.

This analysis revealed that all five intersections have higher than average crash rates for comparable intersections in the State, and all study intersections are in the highest one-third of crash rates for comparable intersections. Furthermore, the intersections at 126th and 146th Streets are specifically flagged as high-crash intersections (top five percent of comparable intersections in the State) with the intersection at 146th Street falling in the top one percent of crash rates at comparable intersections.

The SR 37 mainline consists of 2 northbound and 2 southbound 12-ft wide travel lanes with a 10-ft outside paved shoulder. Inside shoulders are paved and 4-ft wide with a roughly 40-ft wide grass median; right- and left-turn lanes are present approaching these intersections. There are no pedestrian or bicycle facilities parallel to SR 37 or crossing SR 37 at the intersections. The existing right-of-way (ROW) along SR 37 varies from 175- to 460-ft wide with the widest portion at the intersections. Table 1 provides an overview of the existing conditions at each study intersection.

Table 1. Existing conditions at study intersections.

Approach	Design Features	SR 37 at 126th Street	SR 37 at 131st Street	SR 37 at 135th Street	SR 37 at 141st Street	SR 37 at 146th Street
Overall	Number of Legs	4	4	4	4	4
	Traffic Control	Signalized	Signalized	Signalized	Signalized	Signalized
	Minor Leg - ROW Width (feet)	80-90	90-125	95-145	55-80	185-220
East Leg	Approach Lanes - Number	2	1	1	1	2
	Approach Lanes – Width (feet)	12	12	12	12	12
West Leg	Approach Lanes - Number	1	1	1	1	2
	Approach Lanes – Width (feet)	12	12	12	12	12

The TOA, mobility study, and subsequent stakeholder discussions identified teardrop roundabout interchanges as the preferred design alternative (figure 2). However, subsequent design decisions determined that the interchange at 135th Street would be a diamond roundabout design with buttonhook ramps, thereby removing the through movement across SR 37 (figure 3), and a Single Point Interchange (SPI) design would be applied to 146th Street (figure 4). INDOT compared the proposed alternative to the existing, No-Build design using predictive methods from chapter 12 (*Urban and Suburban Arterials*), chapter 18 (*Predictive Method for Freeways*), and chapter 19 (*Predictive Method for Ramps*) in the HSM (AASHTO, 2010; AASHTO, 2014).

Figure 2. Graphic. Proposed teardrop roundabout interchange at SR 37 and 126th Street.

Figure 3. Graphic. Proposed diamond roundabout interchange at SR 37 and 135th Street.

Figure 4. Graphic. Proposed SPI at SR 37 and 146th Street.

INDOT developed future crash predictions for a 21-year period between 2018 and 2038. A joint research effort between Purdue University and INDOT re-estimated a series of project-level safety performance functions (SPFs) and crash modification factors (CMFs) using observed Indiana data over a three-year study period. These SPFs and CMFs more accurately reflect Indiana's observed outcomes, and the resulting SPFs and CMFs can be incorporated into the Interactive Highway Safety Design Model (IHSDM) software format.

The DOT applied the Indiana-specific SPFs to predict crashes for individual design alternatives and applied Indiana-specific CMFs to augment predictions based on proposed infrastructure changes. If relevant CMFs were unavailable, INDOT considered crash history and applied engineering judgment to refine assessments of future safety conditions. INDOT separately analyzed individual facility types for the No-Build and proposed designs using the IHSDM software (version 14.0.0). These individual components included:

- Mainline segments.
- Intersections.
- Entrance and exit ramps.
- Ramp terminals.
- Crossing street segments.

INDOT obtained the necessary geometric and operational inputs including segment length, design speed, annual average daily traffic (AADT), ramp locations, merge distances, and horizontal curvature. INDOT derived analysis inputs from the design plan sets, survey files, and aerial photography. INDOT used traffic volume data based on the most recent historical data (2018) and the design-year volume forecasts (2038).

Analysis Details

The No-Build option consisted of 63 homogenous mainline segments (e.g., non-intersection sections) and the 5 intersection locations in IHSDM. The Build alternative has a simpler mainline segment design (i.e., consistent mainline cross-section geometry throughout the study area); however, the freeway conversion required INDOT to consider crash impacts at speed change lanes, entrance and exit ramps, and ramp terminals on the cross street.

INDOT applied a State-approved CMF to ramp terminal crashes for the three teardrop roundabout interchange locations at 126th, 131st, and 141st Street. The CMF to *convert signalized intersection to a roundabout* was 0.876 for total crashes, and 0.339 for fatal and injury (FI) crashes; this means that the installation of teardrop roundabouts at the interchange ramp terminals would result in a 22-percent reduction in total crashes and 66-percent reduction in FI crashes when compared to the signalized intersections in the No-Build option.

Since there are no cross-street terminals in the proposed 135th Street design, there is no direct comparison between the Build and No-Build options; however, the Build option had to consider predicted ramp and speed change-lane crashes. The report indicated that there is no CMF for the conversion of a signalized intersection to an SPI interchange terminal. INDOT used the percentage of AADT along each approach to convert the two signalized ramp terminals to a simplified diamond interchange with a single signalized interchange terminal. Although INDOT noted that this approach may result in an inaccurate crash prediction, crash estimates at this interchange location made a negligible difference in the project-wide analysis outcome.

INDOT did not apply an Empirical-Bayes (EB) approach when analyzing both alternatives. The EB method relies on historic crash data to determine the expected number of crashes on a corridor or at an intersection given a set of geometric and operational conditions. As INDOT notes in their final report (INDOT, 2018, p. 8):

> "When major alignment or intersection geometry changes are proposed (such as the proposed Teardrop Roundabout Interchange or SPI), it is not used because there is only a small difference in the results obtained from the predictive method when it is used with or without the EB Method. Therefore, 'if the EB Method is not applied consistently, such differences will likely introduce a small bias in the comparison of expected crash frequency among alternatives' (HSM Supplement, 2014). Therefore, the results are presented without the EB method adjustment."

INDOT relied on the predicted number of crashes to compare the Build and No-Build alternatives.

Results

Tables 2 and 3 summarize the total, FI, and property damage only (PDO) crash prediction results for the No-Build alternative, and tables 4 and 5 detail the crash prediction results of the Build alternative.

Table 2. SR 37 No-Build Alternative – crash prediction results by location.

Location	Description	Predicted Total Crashes (2018-2038)	Predicted FI Crashes (2018-2038)	Predicted PDO Crashes (2018-2038)
Segment 1-6	Begin Project to 126th	178	46	132
Intersection	SR 37 and 126th	271	100	171
Segment 7-18	126th to 131st	278	74	204
Intersection	SR 37 and 131st	225	83	142
Segment 19-30	131st to 135th	235	63	172
Intersection	SR 37 and 135th	138	52	86
Segment 31-42	135th to 141st	276	72	203
Intersection	SR 37 and 141st	234	86	148
Segment 43-55	141st to 146th	239	63	176
Intersection	SR 37 and 146th	201	72	129
Segment 56-63	146th to End Project	162	41	121

Table 3. SR 37 No-Build Alternative – crash prediction results; entire project.

Description	Predicted Total Crashes (2018-2038)	Predicted FI Crashes (2018-2038)	Predicted PDO Crashes (2018-2038)
No-Build Intersection Total	1,070	394	676
Intersection Total per Year	**51**	**19**	**32**
No-Build Segment Total	1,368	360	1,009
Segment Total per Year	**65**	**17**	**48**
No-Build Project Total	2,438	753	1,685
Project Total per Year	**116**	**36**	**80**

Table 4. SR 37 Build Alternative – crash prediction results by location.

Location	Description	Predicted Total Crashes (2018-2038)	Predicted FI Crashes (2018-2038)	Predicted PDO Crashes (2018-2038)
Freeway	Through Lanes	617	193	424
	Ramp Connection Sections (Speed Change Lanes)	203	65	138
Interchange	126th NW Ramp (SB Off Ramp)	14	5	8
	126th SE Ramp (NB Off Ramp)	18	7	11
	126th NE Ramp (NB On Ramp)	5	2	3
	126th SW Ramp (SB On Ramp)	12	5	7
	126th NB Ramp Terminal	175	22	153
	126th SB Ramp Terminal	182	22	160
Interchange	131st NW Ramp (SB Off Ramp)	7	3	4
	131st SE Ramp (NB Off Ramp)	10	4	6
	131st NE Ramp (NB On Ramp)	4	2	2
	131st SW Ramp (SB On Ramp)	6	3	3
	131st NB Ramp Terminal	90	12	78
	131st SB Ramp Terminal	102	13	89
Interchange	135th NW Ramp (SB Off Ramp)	3	1	2
	135th SE Ramp (NB Off Ramp)	2	1	1
	135th NE Ramp (NB On Ramp)	3	1	2
	135th SW Ramp (SB On Ramp)	3	1	2
Interchange	141st NW Ramp (SB Off Ramp)	14	6	8
	141st SE Ramp (NB Off Ramp)	14	6	8
	141st NE Ramp (NB On Ramp)	5	2	3
	141st SW Ramp (SB On Ramp)	10	4	6
	141st NB Ramp Terminal	170	19	151
	141st SB Ramp Terminal	136	15	121
Interchange	146th NW Right Ramp (SB Off)	8	3	5
	146th SE Right Ramp (NB Off)	4	2	2
	146th NE Right Ramp (NB On)	2	1	1
	146th SW Right Ramp (SB On)	3	1	2
	146th NW Ramp (SB Off Ramp)	25	10	16
	146th SE Ramp (NB Off Ramp)	21	8	13
	146th NE Ramp (NB On Ramp)	20	8	12
	146th SW Ramp (SB On Ramp)	21	8	13
	146th Ramp Terminal	205	69	136

Table 5. SR 37 Build Alternative – crash prediction results; entire project.

Description	Predicted Total Crashes (2018-2038)	Predicted FI Crashes (2018-2038)	Predicted PDO Crashes (2018-2038)
Build Interchange Total	1,295	268	1,027
Interchange Total per Year	**62**	**13**	**49**
Build Freeway Total	820	258	562
Freeway Total per Year	**39**	**12**	**27**
Build Project Total	2,115	527	1,590
Project Total per Year	**101**	**25**	**76**

Table 6 summarizes the detailed results in tables 2 through 5 to directly compare the crash prediction results for the Build and No-Build alternatives.

Table 6. SR 37 final crash prediction results (crashes per year; 2018-2038).

Alternative	Segment/ Freeway		Intersection/ Interchange		Total	
	Total Crashes	FI Crashes	Total Crashes	FI Crashes	Total Crashes	FI Crashes
No-Build	64	17	51	19	116	36
Build	39	12	62	13	101	25

Based on INDOT's analysis, the Build option would result in 13-percent fewer total crashes per year, as well as 30-percent fewer FI crashes per year.

Documentation and Use of Analysis Results

While the final report is not available to the public, INDOT developed a comprehensive final report of the analysis that contains the results of the original mobility report and the outputs of the IHSDM crash analysis (INDOT, 2018). The results of the analysis pointed to a critical tradeoff in the teardrop roundabout design. Although the roundabout design led to a significant reduction in FI crashes, the analysis also predicted a higher total crash frequency at intersections/interchanges over the 21-year study period compared to the No-Build alternative. For the project as a whole, INDOT predicted that both total crashes and FI crashes will decrease as a result of the conversion to a controlled-access freeway.

Challenges

INDOT identified several key challenges. First, the IHSDM ramp terminal method does not specifically allow users to program a teardrop roundabout or an SPI as the terminal configuration. This is limited to a more typical diamond or partial cloverleaf design. INDOT analysts applied a simplifying assumption to create an operationally similar diamond interchange design and applied the roundabout CMF to calculate crash predictions at relevant ramp terminals.

For the interchange at 146th Street, INDOT made simplifying assumptions based on the distribution of AADT to convert the two signalized intersections into the SPI. Without a relevant CMF, INDOT has limited confidence in these results, but their impact is negligible on the total project (i.e., 205 total crashes in the Build alternative, as opposed to 201 total crashes in the No-Build alternative).

Finally, due to the major changes proposed under the Build design, INDOT was not able to effectively use the EB method to compare both alternatives. The EB method provides greater confidence in the reliability of estimates of expected future crashes; however, the HSM recommends against applying the EB method to major redesigns that completely reshape the operational performance of a corridor. INDOT relied on the Indiana-specific CMF-derived predicted crash values to provide insights into future crashes.

Conclusions and Lessons Learned

INDOT took guidance from several chapters of the HSM and used detailed geometric design elements to analyze significant differences between the Build and No-Build options. Analysts investigated each facility type independently, and the cumulative impacts of each design component predicted the total impact of the SR 37 freeway conversion. INDOT's *SR 37 Predictive Safety Report* (INDOT, 2018) provides an example of how the HSM and IHSDM can be used to demonstrate a safety benefit for projects originally developed for other transportation needs (e.g., operational performance). Operational LOS and capacity needs identified teardrop roundabouts as the preferred interchange improvements; however, the HSM and supporting predictive safety analysis provide transportation planners and engineers confidence that these operational improvements will not come at the expense of safety.

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