Michigan Department of Transportation

Michigan’s US 31 at I-94 Interchange Alternatives Analysis

SAFETY DATA CASE STUDY

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16. Abstract
Since 1981, the Michigan Department of Transportation (MDOT) has worked with the Federal Highway Administration to complete the US 31 freeway connection between I-80/90 in northern Indiana to I-94 in Berrien County, Michigan. The latest construction on the US 31 freeway ended in 2003 with a terminal interchange at Napier Avenue in Berrien County. The original US 31 alignment planned to connect the new freeway to the existing I-94 and I-196 interchange northeast of Benton Harbor, Michigan. However, MDOT identified a sensitive natural resource and endangered species habitat south of the I-94 and I-196 interchange. Since this discovery, MDOT identified an acceptable tie-in at the I-94 and I-94 Business Loop partial interchange east of Benton Harbor. This case study presents MDOT’s iterative approach to project development that used the Interactive Highway Safety Design Model (IHSDM) software to identify a preferred design alternative based on a broad suite of traffic, safety, and cost considerations. The strategic application of IHSDM allowed MDOT to assess different design alternatives and project assumptions to make data-driven decisions for the proposed I-94 and US 31 interchange and surrounding network.

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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
EIS	Environmental Impact Statement
FHWA	Federal Highway Administration
HSM	Highway Safety Manual
IACR	Interchange Access Change Request
IHSDM	Interactive Highway Safety Design Model
MDOT	Michigan Department of Transportation
LOS	level of service
SPF	safety performance function
TCAT	Traffic Crash Analysis Tool
TIA	Transportation Improvement Association
TOA	Traffic Operations Analysis
TWCLTL	two-way center left turn lane

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Executive Summary

Since 1981, the Michigan Department of Transportation (MDOT) has worked with the Federal Highway Administration to complete the US 31 freeway connection between I-80/90 in northern Indiana to I-94 in Berrien County, Michigan. The latest construction on the US 31 freeway ended in 2003 with a terminal interchange at Napier Avenue in Berrien County. The original US 31 alignment planned to connect the new freeway to the existing I-94 and I-196 interchange northeast of Benton Harbor, Michigan. However, MDOT identified a sensitive natural resource and endangered species habitat south of the I-94 and I-196 interchange. Since this discovery, MDOT identified an acceptable tie-in at the I-94 and I-94 Business Loop partial interchange east of Benton Harbor. This case study presents MDOT's iterative approach to project development that used the Interactive Highway Safety Design Model (IHSDM) software to identify a preferred design alternative based on a broad suite of traffic, safety, and cost considerations. The strategic application of IHSDM allowed MDOT to assess different design alternatives and project assumptions to make data-driven decisions for the proposed I-94 and US 31 interchange and surrounding network.

Introduction

The Transportation Research Board's Safety Performance and 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"). The Federal Highway Administration (FHWA) 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 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.

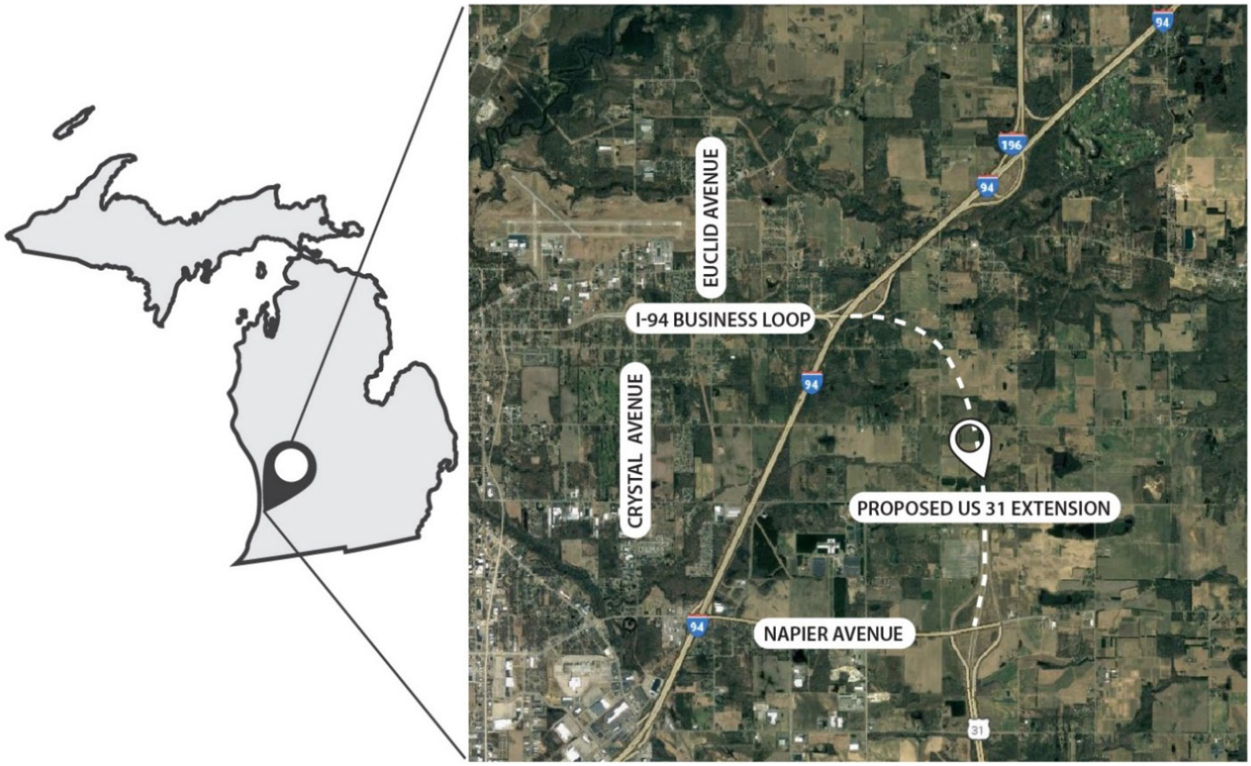
Background

Since 1981, the Michigan Department of Transportation (MDOT) has worked with FHWA to complete the US 31 freeway connection between I-80/90 in northern Indiana to I-94 in Berrien County, Michigan. The latest construction on the US 31 freeway ended in 2003 with a terminal interchange at Napier Avenue in Berrien County (figure 1). The original US 31 alignment planned to connect the new freeway to the existing I-94 and I-196 interchange northeast of Benton Harbor, Michigan. However, MDOT identified a sensitive natural resource and endangered species habitat south of the I-94 and I-196 interchange (the Blue Creek Fen). Since this discovery, MDOT identified an acceptable tie-in at the I-94 and I-94 Business Loop (I-94BL) partial interchange east of Benton Harbor (HNTB, 2020a). This case study presents an interchange alternatives analysis and subsequent safety evaluation performed by MDOT as a part of the much larger US 31 extension and realignment project.

MDOT plans to connect US 31 between Napier Avenue and I-94. MDOT will build a new interchange at the existing I-94 and I-94BL connection that accommodates US 31 and allows free-flow movements for major system-to-system ramps. As part of this freeway extension, MDOT and its consultant, HNTB™, prepared a mobility report that considered the operational impacts of a substantial conversion of the existing interchange to four interchange Build alternatives:

1) Full cloverleaf.
2) Partial cloverleaf with three loops.
3) Partial cloverleaf with a loop.
4) Partial cloverleaf with two loops.

Once MDOT had a preferred interchange alternative design, the agency conducted a safety and mobility evaluation of the affected local network and developed a formal Interchange Access Change Request (IACR) document for FHWA's consideration.



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

Figure 1. Graphic. I-94/US 31 project location.

Purpose and Need

The US 31/I-94 interchange analysis, as well as the broader US 31 realignment project, focused on four primary needs (HNTB, 2020a):

1) Improve mobility along the US 31 corridor with freeway system linkage to I-94.
2) Enhance local access along I-94BL.
3) Provide system-to-system connectivity along US 31 to relieve traffic congestion on Napier Ave, and improve access from I-94 to downtown Benton Harbor.
4) Minimize surrounding environmental impacts in light of current regional needs and traffic projections.

Project Description

- **Sponsoring agency:** MDOT.
- **Project location:** Benton Harbor, Berrien County, Michigan.
- **Project bounds and length of project:** In addition to the I-94/I-94BL interchange, the overall FHWA-approved project study area included the following locations:
    - I-94 from Britain Avenue to I-196.
    - The I-196/I-94 interchange and ramps.
    - The I-94/I-94BL interchange and ramps.
    - The I-94/Napier Avenue interchange, including ramps and ramp terminals on Napier Avenue.
    - The US 31/Napier Avenue interchange, including ramps and ramp terminals on Napier Avenue.
    - The I-196/Red Arrow interchange, including ramps but not the ramp terminals.
    - The I-94BL between I-94 and Urbandale Avenue, including Euclid and Crystal avenues.
- **Facility type(s):** 6-lane divided freeway (I-94), 4-lane divided freeway (I-94BL and US 31), and arterial roads.
- **Area type:** Urban.
- **Project status (spring 2021):** Under construction.

Safety Performance Analysis

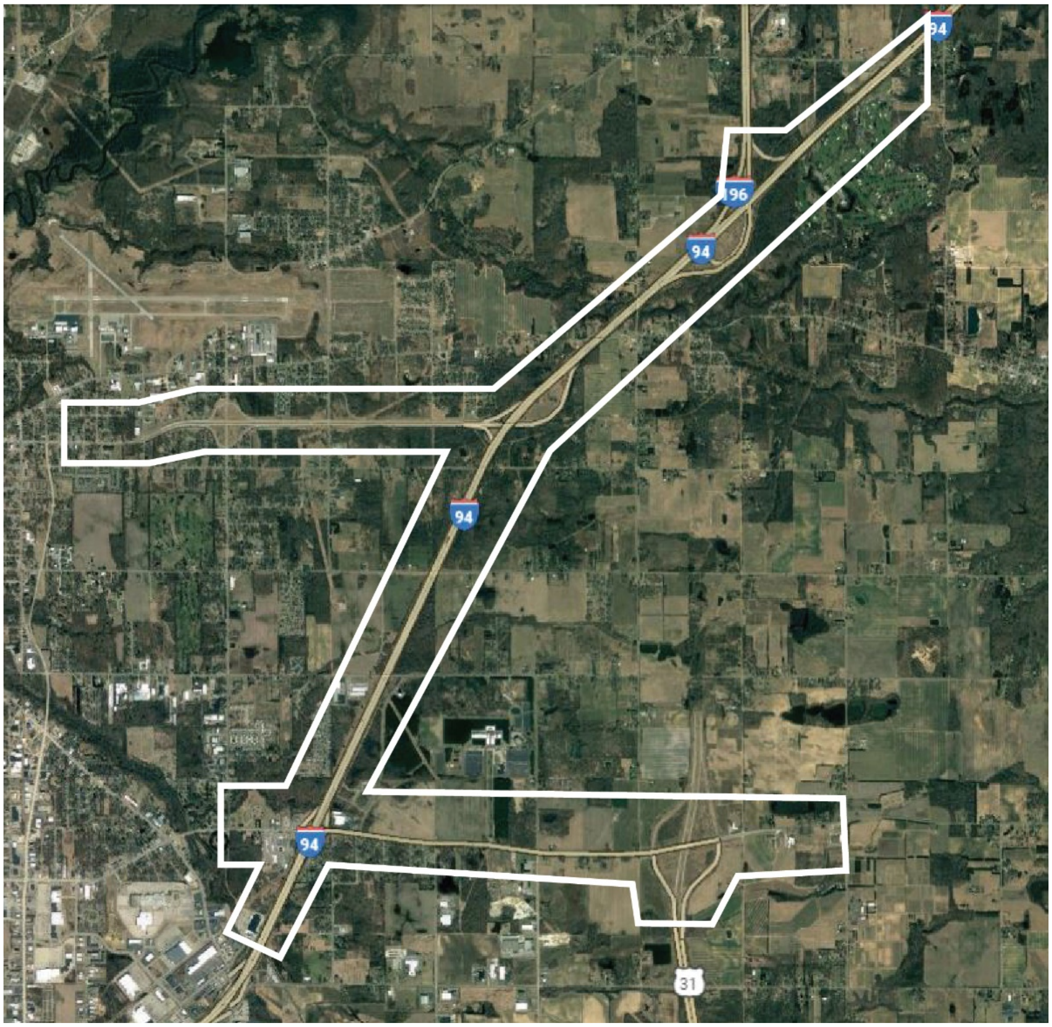
This section provides an overview of the existing safety conditions for the US 31 extension project, the interchange alternatives assessment findings, and the predictive analysis that compared the preferred Build alternative to the "No Build" option. MDOT's approach considered a broad impact on the local network as part of the US 31 extension. Through this iterative process, MDOT made strategic changes to the final design to develop safety improvements at key locations in the project design.

Existing Safety Conditions

This section provides an overview of MDOT's analysis of existing safety conditions. This assessment of historic crash trends informed the alternatives analysis, as well as the trade-offs that produced the final design.

Study Area

MDOT developed a study area that incorporated a broad view of the overall US 31 extension project. This analysis included interchanges along I-94, US 31, I-196, and I-94BL, as well as bidirectional mainline segments on I-94, US 31, I-94BL, and Napier Avenue (figure 2).



Note: The white lines were added by the authors to delineate the project bounds.

Figure 2. Graphic. Safety analysis project extents.

MDOT analyzed historic crashes within the study area to evaluate existing traffic safety concerns and identify potential mitigation measures for critical safety issues. MDOT obtained crash data for a five-year period between 2014 and 2018 from the Transportation Improvement Association's (TIA) Traffic Crash Analysis Tool (TCAT). The TIA is independent from MDOT, but it assists the State with transportation safety data, research, and education. Tables 1 and 2 summarize the crash history for freeway mainline and arterial segments, as well as ramps within the project study area (HNTB, 2019b).

Table 1. Summary of project area crash history by facility type and severity.

Crash Severity	Freeway Mainline Segments	Arterial Segments	Ramps
Fatal	4	0	0
Serious Injury	10	2	2
Minor Injury	16	8	8
Possible Injury	52	32	16
Property Damage Only	601	136	122
Total	**683**	**178**	**148**

Table 2. Summary of project area crash history by facility type and crash type.

Crash Type	Freeway Mainline Segments	Arterial Segments	Ramps
Single Vehicle	455	31	82
Sideswipe - Same Direction	119	24	19
Rear-End	86	40	33
Other	12	0	6
Angle	10	51	7
Head-On	1	1	0
Head-On Left Turn	0	13	0
Rear-End Left Turn	0	1	0
Rear-End Right Turn	0	5	0
Sideswipe – Opposite Direction	0	7	1
Backing	0	5	0
Total	**683**	**178**	**148**

To supplement traditional crash summaries, MDOT conducted site visits and drove the corridor to identify more qualitative observations of the study area. Based on the existing conditions analysis, MDOT developed the following recommendations for future interchange and mainline corridor designs:

- Provide additional paved shoulder width to allow more room for vehicles to recover from a loss of control.
- Improve drainage to prevent water from collecting in travel lanes during inclement weather.
- Install lighting along I-94BL corridor.
- Install chevrons with flashers and other signage intended to reduce speed at interchange ramps.
- Provide standard acceleration and deceleration lengths to all ramps.

Interchange Alternatives Assessment

Before identifying a final alternative to compare against a potential No-Build scenario, MDOT prepared five conceptual designs for a future interchange between US 31 and I-94. The project team refined these conceptual designs with qualitative assessments and engineering judgment into four final practical alternatives: three alternatives from the original five (alternatives 1, 2, and 3) and an additional alternative developed during the collaborative discussion process (alternative 6). MDOT conducted a series of quantitative analyses that included a Peak Period Traffic Operations Analysis (TOA) to determine the effects of each alternative on traffic congestion and a predictive crash analysis using the Interactive Highway Safety Design Model (IHSDM) software. Through this combination of traffic and safety modeling, the MDOT project team iterated through a series of design tradeoffs associated with each alternative to arrive at a final, preferred alternative. Figures 3, 4, 5, and 6 provide an illustration and the following sections provide a general summary of each practical interchange alternative.

Build Alternative 1 (PA-1) was the recommended alternative selected in a 2004 Environmental Impact Statement (EIS). This full cloverleaf interchange would provide free-flow access for all movements with one-lane ramps (figure 3). No stop-controlled movements would be required in the interchange. Weaving would be required along US 31 and I-94 for traffic entering and exiting the ramps (HNTB, 2020b). MDOT's analysis of this alternative noted the following advantages and disadvantages (HNTB, 2019a, p. 18).

Advantages

- All movements would be free flow.
- Relatively higher speed movements.
- Minimized traffic conflict points.
- Lowest number of expected crashes along US 31 and I-94BL.

Disadvantages

- Two bridges within I-94/US 31 interchange.
- Highest construction cost.
- Highest potential for county drain realignment.
- Highest impervious pavement area with greatest detention required.
- Largest footprint with no opportunity for excess right-of-way.

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Figure 3. Graphic. Build alternative 1.

Build Alternative 2 (PA-2) was a partial cloverleaf layout with loop ramps in two quadrants (figure 4). All movements would free-flow off of the ramps, except for the ramps from NB US 31 and SB US 31 which would require a left-turn from US 31. No access for the movement from EB I-94 to SB US 31 would be permitted. No weave sections would be required in this alternative on either I-94 or US 31 (HNTB, 2020b). MDOT's analysis of this alternative noted the following advantages and disadvantages (HNTB, 2019a, p. 20).

Advantages

- Provided free flow movements between NB/SB US 31 and I-196.
- One bridge within I-94/US 31 interchange.
- No weaving between loop ramps within interchange.
- Reduced potential for required county drain realignment.
- Reduced impervious pavement area with potential for reduced detention.
- Reduced construction cost (compared to PA-1).
- Lower number of expected crashes along I-94 compared to PA-1.

Disadvantages

- Not all movements within I-94/US 31 interchange would be free flow.
- Introduced traffic conflict points at ramp terminals on US 31 and I-94BL.
- Higher travel times between US 31 and I-196 compared to PA-1.
- No I-94 EB to US 31 SB movement would be provided.

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Figure 4. Graphic. Build alternative 2.

Build Alternative 3 (PA-3) was another partial cloverleaf configuration, with only one loop ramp and more directional ramps compared to PA-2; this created two intersections in the interchange (figure 5). US 31 would be converted to an undivided roadway prior to the interchange, requiring one four-lane bridge over I-94. This alternative would remove the ramps from SB US 31 to EB I-94, NB US 31 to WB I-94, and EB I-94 to WB US 31. Left-turning movements would accommodate these movements at the ramp terminals. No weave sections would be required along either I-94 or US 31 (HNTB, 2020b). MDOT's analysis of this alternative noted the following advantages and disadvantages (HNTB, 2019a, p. 22).

Advantages

- Provided free flow movements between NB/SB US 31 and I-196.
- No weaving between loop ramps within the interchange.
- Reduced potential for required county drain realignment.
- Reduced impervious pavement area with potential for reduced detention.
- Reduced construction cost (compared to PA-1).

Disadvantages

- Not all movements within I-94/US 31 interchange are free flow.
- Introduced traffic conflict points at ramp terminals on US 31 and I-94BL.
- Higher travel times between US 31 and I-196 compared to PA-1.

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Figure 5. Graphic. Build alternative 3.

Build Alternative 6 (PA-6) utilized a partial cloverleaf as well. This was a hybrid design between PA-1 east of I-94 and PA-2 west of I-94 (figure 6). All movements would be accommodated in this interchange design with most movements being free flow. The elimination of the loop ramp in the northwest quadrant allowed the outer connection ramp to be tightened and compressed the interchange footprint. The elimination of this loop ramp also removed the unbalanced weave WB on I-94 presented in PA-1 (HNTB, 2020b). MDOT's analysis of this alternative noted the following advantages and disadvantages (HNTB, 2019a, p. 24).

Advantages

- Provided free flow movements between NB/SB US 31 and I-196.
- Eliminated weaving between loop ramps along NB US 31/I-94BL and WB I-94.
- Minimized traffic conflict points.
- Lowered travel times between US 31 and I-196.

Disadvantages

- Two bridges within I-94/US 31 interchange.
- Introduced traffic conflict points at west ramp terminals for US 31 NB to I-94 WB movement.
- Higher construction costs.
- Higher impervious pavement area with greater detention required.
- Larger footprint with less opportunity for excess right-of-way as compared to PA-2 and PA-3.
- Higher number of expected crashes along I-94 as compared to PA-2 and PA-3.

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Figure 6. Graphic. Build alternative 6.

The traffic analysis used Vissim™ traffic simulation software. Table 3 summarizes the relevant findings from the alternatives analysis (HNTB, 2019a, p. 27).

Table 3. Summary of alternatives analysis findings.

Criteria	PA-1	PA-2	PA-3	PA-6
Impervious Area (square feet)	4,975,000	4,607,000	4,566,000	4,809,000
Total Cost (all segments)	$131,005,000	$119,958,000	$121,542,000	$127,016,000
Minimize impacts to the surrounding environment	Acceptable	Good	Good	Good/ Acceptable
Reduce construction costs from those estimated for the 1981 EIS alignment	Acceptable	Good	Good	Good/ Acceptable
Improve the efficiency of north-south vehicular travel and the movement of goods and services throughout the entire US 31 corridor	Good	Good	Good	Good
Improve local access within Berrien County	Good	Good	Good	Good
Provide free-flow system connectivity through a north-south US 31 freeway linkage to the I-94 freeway	Good	Good	Good	Good
System-to-system connectivity and linkage	Good	Good/ Acceptable	Good	Good
Relief of traffic congestion on Napier Avenue	Good	Good	Good	Good
Improved access to I-94 and I-94BL to assist economic development	Good	Good	Good	Good
Free-flow movement for traffic to access I-94, I-196, US 31 north, I-94BL from the existing US 31 freeway	Good	Acceptable	Acceptable	Good/ Acceptable

The weekday AM and PM peak period models showed that all Build alternatives have a level of service between A to C in the future year (2041). For safety comparisons, MDOT used IHSDM to predict crashes along I-94 based on each of the four alternatives. For example, Table 4 shows that PA-2 and PA-3 had the lowest annual predicted crashes on I-94.

Table 4. Predicted crashes per year on I-94.

Crash Severity	PA-1	PA-2	PA-3	PA-6
Total Crashes	41.83	39.57	39.56	40.95
Fatal and Injury Crashes	13.34	12.69	12.68	13.12
Property Damage Only Crashes	28.48	26.89	26.88	27.82

Based on the cumulative safety, operational, and environmental impact results, MDOT developed an additional alternative to improve the expected safety performance of the most promising design. The new alternative functionally matched the operational movements from PA-2, so no additional traffic analysis, safety analysis, or cost calculations were performed. Small modifications to PA-2 allowed the MDOT project team to address small concerns within the overall design to derive the final preferred alternative (e.g., incorporating painted gores to separate traffic at ramp conflicts). Figure 7 illustrates the final preferred alternative used in MDOT's IACR analysis.

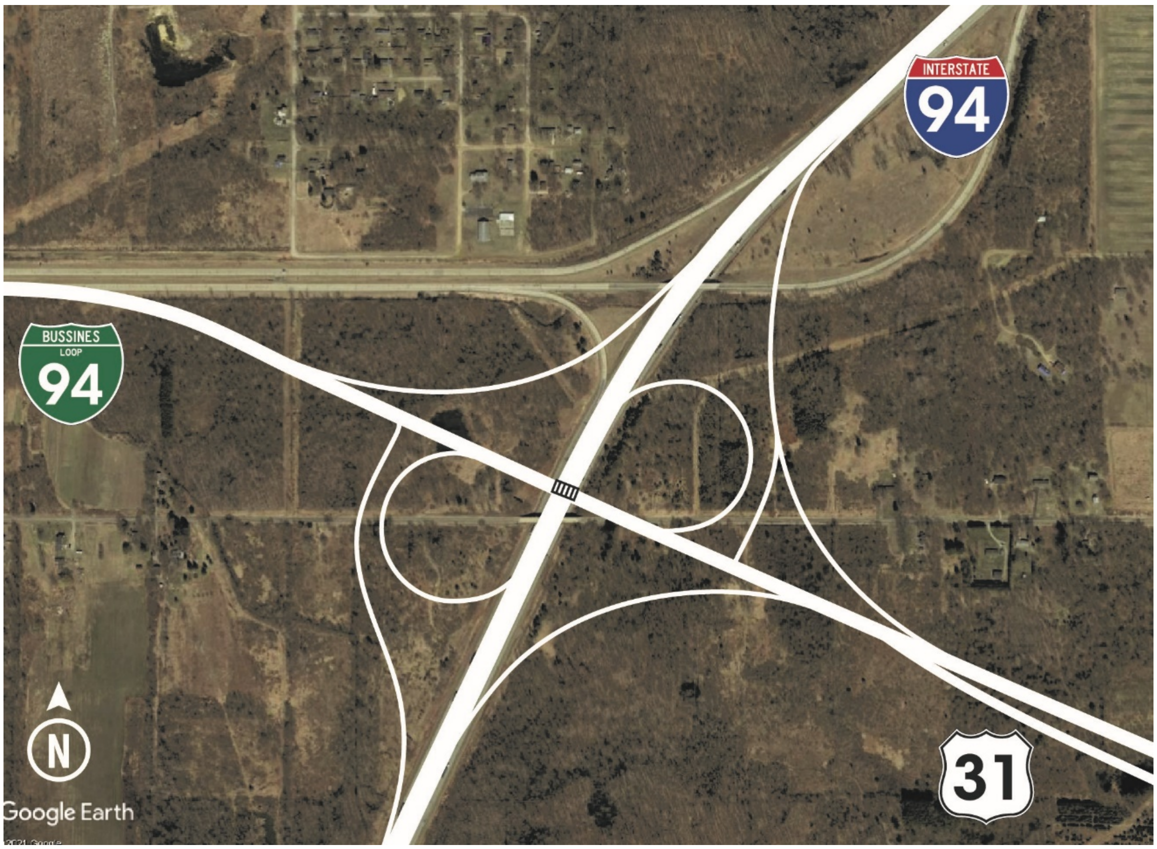

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Figure 7. Graphic. Modified alternative 2 and the final preferred alternative.

Predictive Analysis

MDOT used the HSM default safety performance functions (SPFs) in IHSDM to conduct a predictive crash analysis to compare the future year (2041) Build and No-Build alternatives. IHSDM uses roadway characteristics and traffic volumes to predict crashes based on the methods outlined in the HSM.

The final proposed Build alternative addressed the project purpose and need by enhancing mobility and addressing environmental concerns (e.g., the Blue Creek Fen). Figure 8 illustrates the location of several design changes within the analysis study area:

1. Extend US 31 north of Napier Ave to I-94.
2. Rebuild the existing interchange at I-94 and I-94 BL to accommodate US 31, I-94, and I-94BL.
3. Resize I-94BL from a four-lane divided highway to a three-lane road, including a two-way center left turn lane (TWCLTL).
4. Add an auxiliary lane along the I-94 EB corridor between the proposed US 31 interchange and the existing I-196 interchange.
5. Reconstruct the I-196 ramps along the existing ramp alignments.

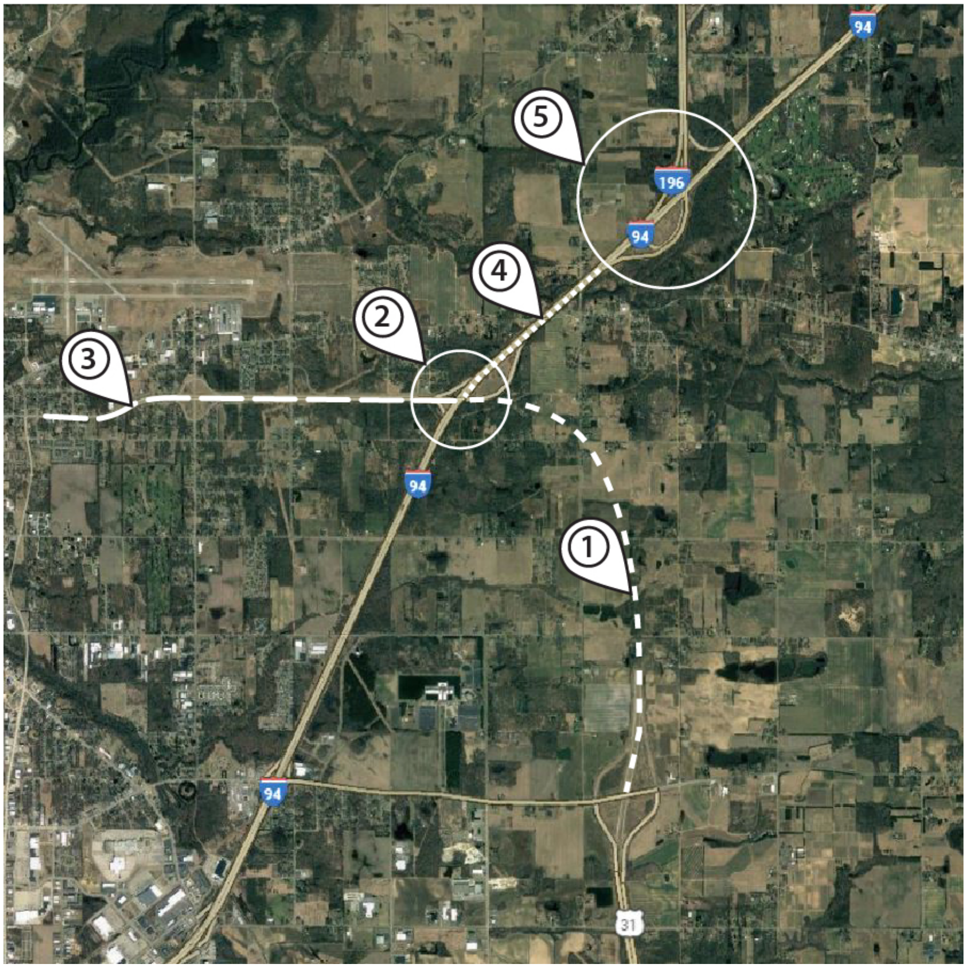

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Figure 8. Graphic. Final proposed Build alternative design changes.

The Peak Period TOA and Vissim™ output provided the traffic estimates for both alternatives. This showed substantial differences that would have a direct impact on anticipated safety performance. For instance, MDOT expected daily traffic volumes on I-94BL to nearly double as a result of the new US 31 connection. Much of this traffic would be diverted from Napier Avenue and I-94 south of the new US 31 interchange in the Build alternative (thereby reducing traffic at these locations). However, the comparison of roadway geometry between both alternatives provided a more complex challenge. The

Build alternative, which included an extension of US 31 between Napier Avenue and I-94, contained substantial design differences that included approximately 3 miles of new freeway segments and 2.17 miles of ramps (a 35-percent increase in road mileage).

The Build design also called for the conversion of a two-way stop-controlled intersection at I-94BL and Crystal Avenue to a single-lane roundabout, as well as the conversion of the bridge at Euclid Avenue and I-94BL (that currently does not allow access between Euclid Avenue and I-94BL) to an at-grade, two-way stop-controlled intersection. To account for crash prediction differences between a two-way stop-controlled intersection and a single-lane roundabout, MDOT applied a crash modification factor (CMF) of 0.7511 to the predicted crash results at the Crystal Avenue intersection (CMF Clearinghouse ID #4930). This reduced the total predicted number of crashes (all severities) at the intersection by 24.89 percent.

Initial Results

MDOT submitted an initial round of crash prediction results to FHWA as part of an IACR in February 2020. Table 5 summarizes these results.

Table 5. Predicted crashes per year – no-build and build alternative.

Model	Total Crashes	Fatal and Injury Crashes	Property Damage Only
No-Build Alternative	130.17	45.55	84.70
Build Alternative	131.07	45.74	85.32
Difference	**0.90**	**0.19**	**0.65**
Percent Change	**0.69%**	**0.41%**	**0.77%**

This analysis predicted a narrow, less than one-percent increase in crashes per year based on the Build alternative design. Although the project team expected the substantial increase in lane mileage and traffic to lead to a slight increase in crashes in most locations, the complete project study area contained locations for potential offsetting crash reductions:

- Reduced crashes on Napier Avenue as a result of redirected (i.e., reduced) traffic.
- Slight crash reductions through ramp and ramp terminal redesigns.
- Crash reductions as a result of the conversion of the Crystal Avenue and I-94BL at-grade diamond interchange to a roundabout.

As a result of this slight increase, MDOT and FHWA worked to refine the Build alternative design, the IHSDM analysis methodology, and the application of relevant CMFs. Based on these discussions, the MDOT project team noted several challenges and changes to the project approach in a subsequent memorandum to FHWA in May 2020 (MDOT and HNTB, 2020).

IHSDM Analysis Challenges

Prior to making changes to the crash prediction analysis, the MDOT project team noted the following limitations with respect to IHSDM or analysis assumptions:

- The project team had to make tradeoffs with respect adding a TWCLTL to I-94BL in IHSDM. The original design of I-94BL was functionally a freeway; however, IHSDM would not return crash prediction results with a TWCLTL located on a freeway. The project team could have classified the road as an arterial to obtain predicted crashes, but the team believed the character of the road (i.e., a two-lane suburban highway) was more in line with a freeway than an arterial. This likely over-estimated crashes in the Build alternative (i.e., a simple two-lane suburban highway) relative to what would be expected under the three-lane cross-section that includes a TWCLTL.
- Prior to the release of IHSDM version 15.0, it was not possible to model a roundabout for an intersection. MDOT submitted its IACR before this version was available, so the project team developed a scenario for the proposed conversion at Crystal Avenue that applied a CMF (#4930) to the existing two-way stop control to represent the conversion to a roundabout.
- The No-Build (i.e., existing) design of the Crystal Avenue and I-94BL intersection is an at-grade diamond interchange with all turn movements accommodated by ramps. Since IHSDM does not allow for an at-grade intersection between a freeway and arterial, the project team did not model this intersection in the No-Build scenario.

Updates to Build Design

The MDOT project team made two fundamental changes to the design after the initial IACR submittal:

1. The Build alternative no longer considered an at-grade intersection at Euclid Avenue and I-94BL; it would remain an overpass.
2. The Build alternative removed a portion of the proposed TWCLTL from Crystal Avenue and the I-94 WB off ramp; however, the Build alternative still considered a TWCLTL between Urbandale Avenue and Crystal Avenue.

Updates to Build Volumes

Based on the removal of the proposed at-grade intersection at Euclid Avenue and I-94BL, the project team adjusted future Build alternative traffic volumes to show traffic being re-routed to Crystal Avenue/I-94BL.

Updates to the Predictive Crash Analysis

The MDOT project team made several adjustments to the revised predicted crash analysis based on the following changes and assumptions:

No-Build Alternative

- Since IHSDM does not allow for an at-grade intersection between a freeway and arterial to be modeled with the overall interchange, MDOT modeled the at-grade intersection separately from the overall project and added the results to the overall results for the Crystal Avenue/I-94BL interchange. The project team accomplished this by modeling the ramps without connecting them to the cross-street in the primary model. Outside of the main model, the project team created the cross-street (Crystal Avenue) and created ramp terminals to model this aspect of the intersection. This allowed the project team to append ramp terminal results to the overall model results from the primary model.

Build Alternative

- The MDOT project team replaced the original CMF for the conversion of a two-way stop-controlled intersection to a roundabout and applied two separate CMFs instead:

    1. A 0.348 CMF (65.2-percent reduction) for all fatal and injury crashes (CMF Clearinghouse ID #4935).
    2. A 0.955 CMF (4.5-percent reduction) for all crashes (CMF Clearinghouse ID #4934).

    This approach more accurately reflected the anticipated changes to fatal and injury crashes relative to total crashes. The project team determined the count of property damage only crashes based on the percentage of fatal and injury and total crashes at the intersection.
- MDOT applied a new CMF to reflect the addition of a TWCLTL on a suburban highway. Rather than modeling a TWCLTL directly in IHSDM, the project team applied a CMF for installing TWCLTLs (CMF Clearinghouse ID #2341) that estimated a 20.3-percent reduction in all crash types for the section of I-94BL that would still receive the treatment (i.e., between Urbandale Avenue and Crystal Avenue).
- MDOT removed the proposed at-grade intersection at Euclid Avenue and I-94BL and redistributed traffic to the proposed Crystal Avenue roundabout.

Revised Results

Based on the aforementioned revisions to the Build and No-Build designs and crash prediction analysis, the MDOT project team reduced the number of predicted crashes per year in the Build alternative relative to the No-Build design (table 6). Although the revised Build design is expected to reduce total crashes by 5 per year, and fatal and injury crashes by 2 per year, over an anticipated future No-Build scenario, the project team noted that not all locations are expected to experience fewer crashes as a result of the project. For instance, the improved connectivity between US 31 and I-94BL in any Build scenario should increase traffic volumes on I-94BL. As a result, even though the improvements on US 31, I-94, and I-94BL should reduce crashes as a whole, MDOT expected crashes on I-94BL alone to increase. Still, MDOT's iterative approach that refined certain design elements, such as the proposed roundabout and TWCLTL on I-94BL, produced a project design that accommodates mobility needs while also reducing predicted crashes.

Table 6. Revised predicted crashes per year – no-build and build alternative.

Model	Total Crashes (Original)	Fatal and Injury Crashes (Original)	Property Damage Only (Original)	Total Crashes (Revised)	Fatal and Injury Crashes (Revised)	Property Damage Only (Revised)
No-Build Alternative	130.17	45.55	84.70	133.55	46.81	86.83
Build Alternative	131.07	45.74	85.32	128.24	44.42	83.98
Difference	**0.90**	**0.19**	**0.65**	**-5.30**	**-2.39**	**-2.86**
Percent Change	**0.69%**	**0.41%**	**0.77%**	**-3.97%**	**-5.11%**	**-3.29%**

Conclusions and Lessons Learned

Although mobility and regional connectivity were the primary purpose and need of the US 31 extension, MDOT's data-driven approach helped refine the final design of a complex project. A preliminary evaluation of recent crash history and site visits identified location-specific opportunities for safety improvement (e.g., installation of lighting, application of low-cost countermeasures, and provision of additional paved shoulder). IHSDM analysis allowed the project team to assess the safety performance of major design decisions and compare predicted safety outcomes with anticipated project benefits (tables 3 and 4). This comparison led to the refinement of the original PA-2 interchange design into the final preferred alternative. Subsequent design revisions across the entire project footprint, based on IHSDM analysis, also led to an alternative that anticipated fewer crashes relative to a No Build scenario (e.g., the removal of the at-grade intersection at Euclid Avenue and I-94BL, as well as the shortening of the TWCLTL on I-94BL).

Through MDOT's iterative process, the project team also noted several key lessons for analyzing a large and intricate project with significant network impacts:

- **Managing expectations is critical.** It is important to be clear about the effectiveness and usefulness of modeling in the decision-making process. There are limitations to what can be modeled, as well as to the efficiency of making large changes to a complex model.
- **Identify when and how modeling will be used early in the process.** Complex safety modeling is an effective method for differentiating clear alternatives. Practitioners and decision-makers should evaluate slight differences in potential alternatives according to preliminary screening criteria and engineering judgment before considering rigorous safety modeling.
- **IHSDM should be used strategically.** Practitioners cannot do everything in IHSDM, and it is important to establish a clear strategy for using IHSDM. Users should apply IHSDM and safety modeling at stages in a project where it can add the most benefit to the decision-making process (i.e., once the project team had defined its preferred alternative designs).

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Contact

Michigan Department of Transportation

Dharmesh Valsadia, Innovative Contracting Project Manager

ValsadiaD@michigan.gov