Optimizing Work Zone Conditions to Maximize Safety and Mobility (OR23-022)

FINAL REPORT

Authors

Jonathan J. Kay, Timothy J. Gates, and Peter T. Savolainen

Michigan State University
Department of Civil and Environmental Engineering
428 South Shaw Lane
East Lansing, MI 48824

Sponsoring Organization

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16. Abstract

Despite the fact that highway work zones represent a required element of maintaining and improving the transportation network, the resulting changes in traffic patterns, narrowed right-of-way, and other construction activities can lead to an increased risk for traffic crashes and related injuries or fatalities. This research sought to identify the critical work zone attributes that are related to improved (or degraded) work zone safety and/or mobility, and ultimately identify cost effective treatments that can achieve high levels of both safety and mobility. The outcomes of the research include a synthesis of prior research and best practices used by other agencies, a benchmark of statewide work zone safety performance, new tools and resources to conduct safety analyses specific to freeway work zones, and recommendations to improve the department's work zone program. This research began with a review of the literature as well as the identification and review of relevant MDOT policies and guidance. Next, a statewide analysis of historical work zone crash data was conducted to quantify recent trends with respect to work zone safety within Michigan along with a comparison to nationwide work zone crash data. Historical models were developed for 25 recent freeway work zones across the state of Michigan to evaluate the safety and mobility impacts associated with implementation of temporary traffic control for long-term construction projects. The work zone projects were selected to provide a distribution of common work zone types, temporary traffic control configurations, types of work, area types, traffic volumes, work durations, and lengths among other factors. These models were used to quantify the safety performance impacts associated with each of the selected freeway construction projects via the Empirical Bayes (EB) method, including the estimated change in crashes at the project-level as well as the estimated change in crashes for each area within the work zone (e.g., advance warning, transition, and activity). Findings from these tasks were aggregated to support the development of recommendations to optimize safety and mobility within Michigan work zones, including recommendations for MDOT's Work Zone Safety and Mobility Manual, a revised Safety & Mobility Decision Tree, and a Microsoft Excel tool.

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Principal Investigator
Timothy J. Gates, PhD., P.E.
Professor

Co-Principal Investigator
Peter T. Savolainen, PhD., P.E.
MSU Foundation Professor

Authors
Jonathan J Kay, Timothy J. Gates, Peter T. Savolainen

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A report from
Michigan State University
Department of Civil and Environmental Engineering
428 South Shaw Lane
East Lansing, MI 48824

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EXECUTIVE SUMMARY

Despite the fact that highway work zones represent a required element of maintaining and improving the transportation network, the resulting changes in traffic patterns, narrowed right-of-way, and other construction activities can lead to an increased risk for traffic crashes and related injuries or fatalities. A total of 5,128 work zone-related traffic crash fatalities occurred across the United States between 2017 and 2022, including 226 workers on foot. Within Michigan, a total of 30,899 work zone related crashes occurred over the same period, including 488 collisions resulting in a fatality or serious injury. Construction or maintenance-related work zone crashes occur across the state – primarily along the interstate and arterial highway network where such work is required to effectively sustain the transportation system.

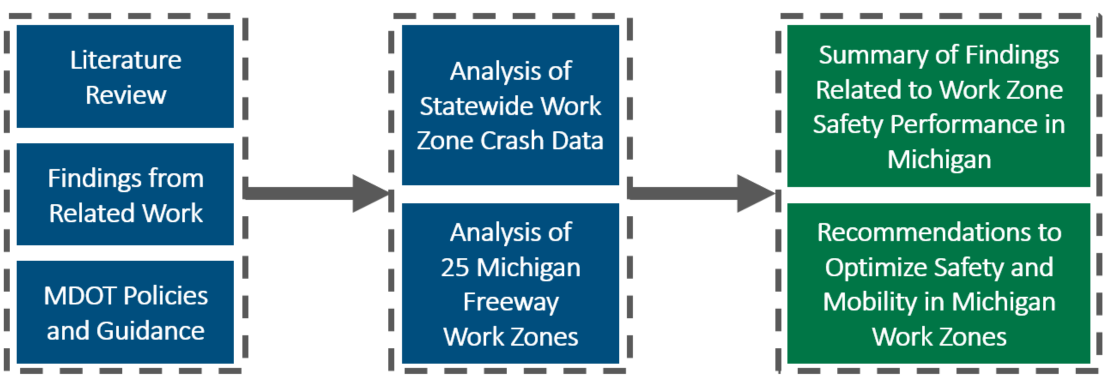
Michigan Work Zone Traffic Crashes (2017-2022)

The federal *Work Zone Safety and Mobility* rule, initially established in 23 CFR 630 in 2004, required that all states develop a "policy for the systematic consideration and management of work zone impacts on all federal aid highway projects across all stages of project planning, development, construction and operations". In response to the federal rule, MDOT established the *Work Zone Safety and Mobility Policy* in 2007, which applies to all construction and maintenance work zones in the state. The processes, procedures, and guidelines to support this policy are detailed in MDOT's *Work Zone Safety and Mobility Manual*, which has been revised several times since its initial publication to be consistent with current best practice. The manual also outlines the department's methods to evaluate safety and mobility within work zones.

Research Objectives and Methods

Consistent with MDOT's commitment to the Safe System Approach, the department sponsored research project OR23-022 (*Optimizing Work Zone Conditions to Maximize Safety and Mobility*) to identify the critical work zone attributes that are related to improved (or degraded) work zone safety and/or mobility, and ultimately identify cost effective treatments that can achieve high levels of both safety and mobility. The outcomes of the research include a synthesis of prior research and best practices, methods for measuring the effectiveness of work zone configurations, recommended strategies to mitigate crashes, and guidance for optimizing safety and mobility for work zones, including recommendations for MDOT's *Work Zone Safety and Mobility Manual,* a revised *Safety & Mobility Decision Tree*, and a *Microsoft Excel tool*.

This research was completed via the methodology outlined below, which began with a review of the literature along with a review of MDOT policies and guidance documents. Next, a statewide analysis of historical work zone crash data was conducted to quantify trends with respect to work zone safety both within Michigan and nationwide. Historical daily models were also developed of 25 freeway work zones across Michigan to evaluate the safety and mobility impacts associated with implementation of various temporary traffic control configurations in long-term construction projects. Findings from each of these tasks were used to develop recommendations and tools to optimize safety and mobility within Michigan work zones.



Overview of Research Methodology

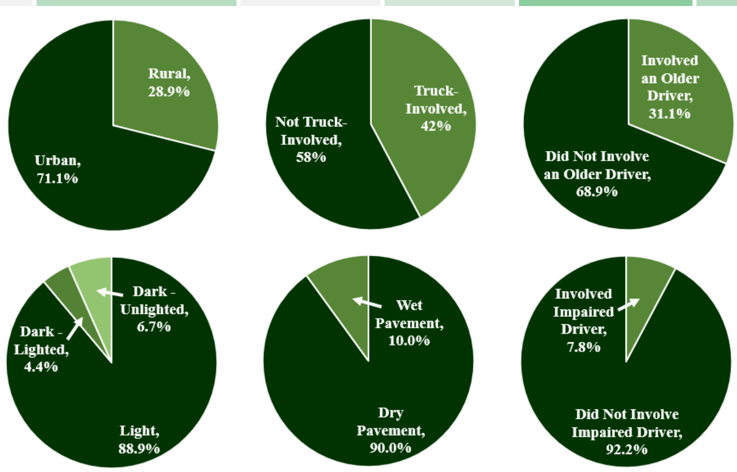
Analysis of Statewide Work Zone Crash Data

A detailed analysis of historical statewide traffic crash data specific to highway work zones was conducted to quantify recent trends with respect to work zone safety both within Michigan and nationwide. Statewide traffic crash records coded as having occurred within a construction or maintenance work zone by the responding officer were collected from the annual databases maintained by the Michigan State Police for the six-year period between 2017 and 2022. National work zone crash data were also collected to compare the national experience with trends observed within Michigan. These data were evaluated to provide a series of findings that can be used as a roadmap to target statewide work zone crash patterns or circumstances to accelerate progress towards MDOT's long-term zero death vision.

For example, given the overrepresentation of rear end crashes in Michigan compared to the national experience (shown below), the identification of safety treatments intended to reduce rear end collisions related to work zone congestion represents the greatest opportunity to accelerate progress towards the state's safety goals. Additional details related to the 90 severe work zone-coded rear end crashes that involved congestion along freeways are presented below.

Michigan vs. National Work Zone Crashes by Crash Type and Severity

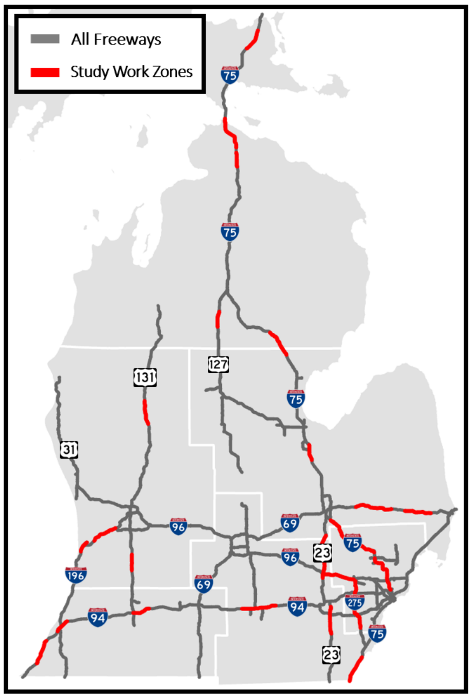
Severity	Location	Crash Type					
		Single Vehicle	Head-On	Angle	Rear End	Sideswipe	Other
Fatal	Michigan	31.7%	1.0%	3.0%	41.6%	6.9%	15.8%
	National	54.4%	7.4%	10.7%	22.8%	3.6%	1.1%
Injury	Michigan	17.4%	3.5%	12.4%	54.1%	9.0%	3.6%
	National	25.6%	2.0%	16.7%	42.8%	11.6%	1.3%
PDO	Michigan	17.4%	1.2%	7.7%	43.7%	24.3%	5.7%
	National	22.4%	0.7%	12.2%	39.4%	23.7%	1.7%



Freeway Fatal/Serious Injury Rear End Crashes involving Work Zone Congestion (N = 90)

Detailed Safety Performance Analysis of Select Freeway Work Zones in Michigan

Historical models were developed for 25 recent freeway work zones across Michigan to evaluate the safety and mobility impacts associated with implementation of temporary traffic control for long-term construction projects. The 25 construction projects were selected to incorporate a broad range of roadway, traffic, and work zone characteristics (such as roadway context, daily traffic volume, and temporary traffic control configuration) across all seven MDOT regions. These projects are shown below, where the 25 study work zones covered approximately 10 percent of Michigan's freeway system.

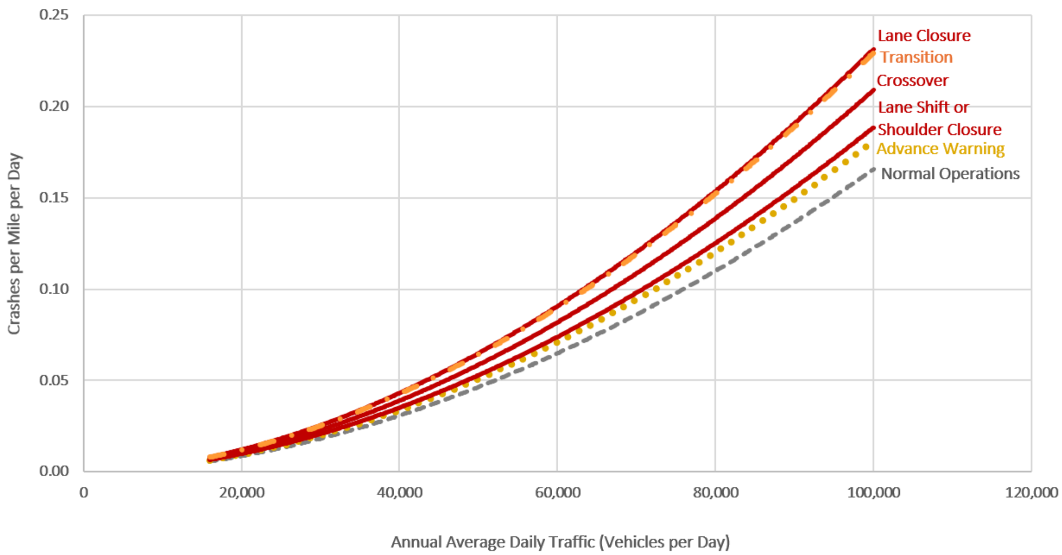


Map of Michigan Freeway Work Zones Evaluated in this Study

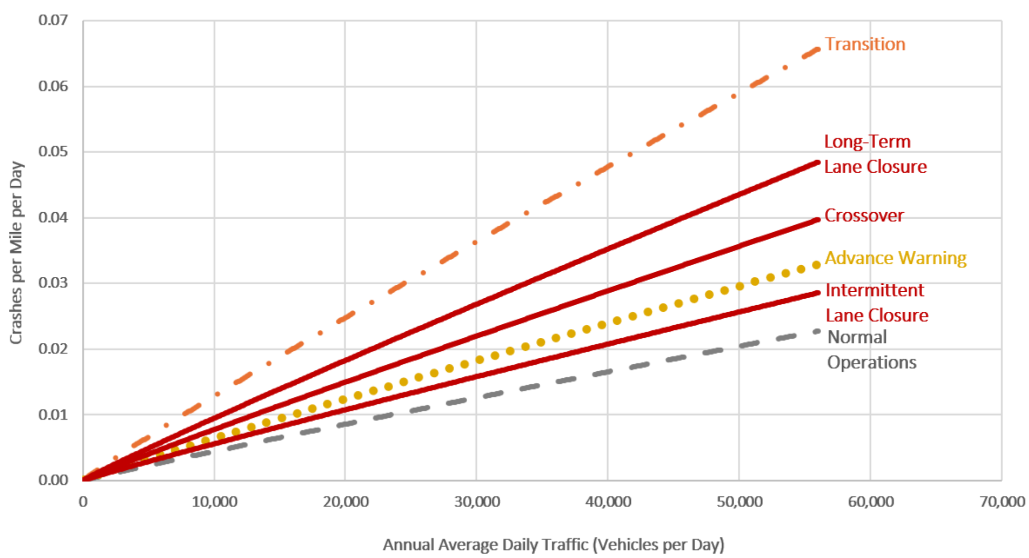
For each of these 25 projects, a multi-stage data collection process was completed in conjunction with MDOT staff to develop daily models of each work zone. These daily models were used to quantify the safety performance impacts associated with each of the study freeway construction projects via the Empirical Bayes (EB) method outlined in the *Highway Safety Manual*. These models were used to quantify the safety performance impacts associated with each of the selected freeway construction projects via the Empirical Bayes (EB) method, including the estimated change in crashes at the project-level. Additionally, the change in crashes for each area within the work zone (e.g., advance warning, transition, and activity) was estimated, with results provided for specific temporary traffic control configurations.

Estimated Change in Crashes during Work Zone Operations by Project Category

Category	Projects	Min AADT	Max AADT	Impact Area Length	Work Days	Crashes during Normal Operations			Crashes during Work Zone Operations		
						Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Urban Freeway Reconstruction Projects with Major Volume Impacts	2	106,400	114,900	71.8	1,559	2,759.0	2,866.5	2,879.6	3,607.0	+727.4	25.3%
High AADT Suburban and Urban Freeways with Recurring Congestion	5	48,200	72,826	161.6	3,006	1,893.4	2,077.4	2,060.5	2,224.0	+163.5	7.9%
Moderate AADT Rural and Suburban Freeways with Low Recurring Congestion	9	25,400	66,200	173.4	4,561	1,242.8	1,262.0	1,267.9	1,675.0	+407.1	32.1%
Low AADT Rural Freeways with Rare Congestion	8	6,000	19,100	160.2	1,959	85.1	72.0	81.2	116.0	+34.8	42.9%
All Sites (*Excluding I-75 Modernization Project*)	**24**	**6,000**	**114,900**	**566.8**	**11,085**	**5,980.4**	**6,277.9**	**6,289.2**	**7,622.0**	**+1332.8**	**21.2%**



Congested Freeway Safety Performance by Work Area: Crashes per Mile per Day versus Annual Average Daily Traffic Volume



Uncongested Freeway Safety Performance by Work Area: Crashes per Mile per Day versus Annual Average Daily Traffic Volume

Summary of Key Findings

The key findings from this research are summarized in the table below. These data-driven findings are specific to Michigan work zones based on the results of the literature review, statewide crash data evaluation, and safety performance analysis of select Michigan freeways. Additional details associated with these findings are found within the final project report.

Summary of Key Findings Related to Work Zone Safety Performance in Michigan

Roadway Type	Finding
All Roadways	• Compared to the national experience, Michigan tends to observe a larger proportion of rear end work zone collisions and a smaller proportion of single vehicle collisions. • Data from the analysis of freeway work zones suggested a considerable underreporting of work zone-coded crashes. Further, there is considerable error within the newly added work zone fields (in particular the construction activity and location fields). • Data from the analysis of freeway work zones provides evidence that construction-season (March-November) and winter-season (December-February) safety performance varies due to increased rates of single-vehicle crashes observed in the winter. As a result, it is critical to consider such seasonal patterns when conducting work zone safety analysis in Michigan.
Freeways	• Nearly half of fatal freeway work zone crashes in Michigan are rear end collisions, compared to approximately one-third of work zone crashes nationwide. • The existing operational conditions along freeway facilities under normal operations (before the implementation of temporary traffic control) have a dramatic effect on the relative impact of a work zone on safety performance. Facilities that experience consistent recurring congestion under normal operations tend observe smaller relative impacts than facilities where such recurring congestion is uncommon. • The rate of rear end collisions was considerably larger than under normal operations as vehicles enter the upstream area, traverse the advance warning area, and enter and the activity area. Rates of rear end collisions were highest within the activity areas (as opposed to in advance of the work zone). • Work zone crashes occurring along freeway ramps are only seven percent of all freeway work zone collisions. Additionally, ramp safety performance on the aggregate does not appear to be considerably degraded as a part of freeway construction efforts.
Arterials	• Michigan has observed a higher share of fatal rear end work zone collisions (27.6 percent) compared to the national experience (12.6 percent). • Michigan has observed a higher share of fatal work zone crashes involving pedestrians (41.4 percent) than the national experience (16.0 percent). • A total of 154 arterial work zone crashes involving pedestrians or bicyclists occurred during the study period, including 57 incidents involving a road worker being struck by a vehicle.

Roadway Type	Finding
	• A key safety concern is the interaction between flaggers and the driving public, where 21 collisions occurred that involved a vehicle striking either a flagger or disregarding flagger control and striking another road worker.
Collectors	• In contrast with the findings for mainline freeways and arterial roadways, rear end collisions comprise a far smaller share of all collector work zone crashes. • A total of 34 collector work zone-coded crashes involving pedestrians or bicyclists occurred during the six-year study period, including 23 incidents involving a road worker being struck by a vehicle. • A key safety concern remains the interaction between flaggers and the driving public, where 17 collisions occurred that involved a vehicle striking either a flagger or disregarding flagger control and striking another road worker.
Local Roadways	• In contrast with all of the other roadway types evaluated in this study, rear end collisions are not the predominant work zone crash type along local roadways. Instead, single vehicle, angle, and other collisions represent the most common crash type across a mix of work activities. • A total of 29 work zone crashes involving pedestrians or bicyclists occurred during the six-year study period, including 19 incidents involving a road worker being struck by a vehicle.

Summary of Recommendations

Based on the findings presented in the prior table, a series of recommended revisions to MDOT's various work zone resources and practices were developed. These recommendations represent data-driven revisions to existing MDOT policies, guidance, and other documents intended to improve safety and mobility within Michigan work zones. The recommendations are primarily focused on the MDOT *Work Zone Safety and Mobility Manual*, including a revised *Safety & Mobility Decision Tree.* The recommendations are summarized in the following table, with full details provided within the report. The revised *Decision Tree* is displayed after the table and references to the *Microsoft Excel tool* are incorporated into the recommendations.

Recommended Revisions to MDOT's Work Zone Resources and Practices

Resource	Recommendation
All Resources	The trends and patterns presented within the statewide evaluation of this report identify areas for the department to target towards reducing both the frequency and severity of work zone collisions. It is critical to note there are a number of factors (including those beyond MDOT's approach to temporary traffic control) that could influence these patterns (such as differences versus other states in the police coding of crash data, the composition of the transportation system, and the types of projects that occurred during the study period). Ultimately, MDOT should seek opportunities within its work zone safety policies and procedures to:

Resource	Recommendation
	• Increase the use of strategies to reduce rear end collisions within all freeway and arterial work zones. The use of such countermeasures should be emphasized throughout the activity area (as opposed to just in advance of the work zone). • Address the patterns of fatal and serious injury collisions occurring within work zones at night with or without lighting present. • Ensure that appropriate focus is placed on rural freeway projects where recurring congestion is rare as these facilities experience the largest relative decrease in safety performance due to construction activities. • Emphasize safety performance for large trucks given the overrepresentation of truck-involved collisions in transition, activity, and termination areas of freeway projects compared to normal conditions. • Continue to emphasize MDOT's freeway ramp typicals as safety performance along these facilities was largely unaffected during work periods. Design for freeways should focus on how ramps influence mainline performance (such as the consideration of potential closures). • Emphasize pedestrian safety performance along arterial work zones as Michigan has experienced a higher share of pedestrian work zone fatalities along these facilities than the United States as a whole. • Emphasize reducing conflicts between traffic regulators and drivers, as such collisions represented one of the most frequent types of collisions between vehicles and pedestrians within non-freeway work zones.
Work Zone Safety and Mobility Manual *And UD-10 Traffic Crash Report 2021 Instruction Manual*	Given the considerable limitations associated with the reliability of the work zone fields included on UD-10 crash report forms, MDOT should avoid using these fields as a part of formal work zone safety analysis discussed within the *Work Zone Safety and Mobility Manual* unless the accuracy of these fields can be improved. Most importantly, the use of the construction type code to identify crashes occurring within a work zone should be minimized as this could lead to potential underreporting of related crashes. Instead, analysts should focus on all non-animal crash records occurring within construction influence areas when collecting traffic crash data as a part of work zone safety analysis (including when using the *Microsoft Excel tool*).
Work Zone Safety and Mobility Manual	All work zone safety performance analyses outlined within the *Work Zone Safety and Mobility Manual* should consider the seasonal differences in safety performance observed between the construction-season (March-November) and winter-season (December-February). This is particularly important when comparing safety performance during periods under normal operations (before the work zone was in place) to periods where active work is underway.
Work Zone Safety and Mobility Manual	Freeway work zone safety performance analysis processes within the *Work Zone Safety and Mobility Manual* should consider the important differences in relative impacts to safety performance for freeways with and without recurring congestion under normal operations. While engineering judgement should be used to determine between uncongested versus congested facilities based on an operational analysis that considers factors beyond average daily traffic volume (such as peak hour factor), the department can generally consider facilities with above average total (71.1) and rear end (27.9) crash rates per 100 million vehicle

Resource	Recommendation
	miles traveled as congested. Consider including a similar conceptual discussion within Section 4.01 of the manual. This is also a required input for analysts to obtain output from the *Microsoft Excel tool*.
Work Zone Safety and Mobility Manual	Given that there was not enough information to estimate the safety performance impacts for a number of temporary traffic control configurations or design strategies, the department should continue to evaluate projects consistent with the methods outlined in this report. For example, data from future projects that include specific temporary traffic control configurations (such as the use of moveable barrier walls) or ITS strategies (such dynamic stopped traffic advisory systems) can be used to provide additional insight into these design elements. Results from future freeway projects evaluated via the *Microsoft Excel tool* could be used to support this process.
Work Zone Safety and Mobility Manual	The data collection process, analytical tools, and project-level findings presented within this report can be used to conduct data-driven safety performance analyses for freeway facilities in support of the required processes outlined within MDOT's *Work Zone Safety and Mobility Manual*. The *Microsoft Excel tool* can also be used to support this process. Additionally, the 25 project profiles presented within the report also represent a resource as a part of seeking information related to similar recent projects.
Work Zone Safety and Mobility Manual	Section 1.05 of the manual discusses annual work zone training activities completed during off-peak construction times. Findings from OR23-022 could be used to support these training activities, including details on conducting work zone safety performance analyses. This could also include specific training to support the use of the *Microsoft Excel tool*.
Work Zone Safety and Mobility Manual	Exhibits 2-1, 2-2, 2-3, 2-4, 2-5 identify many of the mitigation strategies discussed within the literature review. In other words, the manual is largely consistent with the current state of practice.
Work Zone Safety and Mobility Manual	Section 2.10.07 and Section 2.10.10 of the mobility manual discuss statewide reviews conducted on a regular basis that include changes in crash trends. The findings presented in this report can be used to inform this process. Additionally, the concerns related to the reliability of the four work zone UD-10 crash report form fields should be considered as a part of this process.
Work Zone Safety and Mobility Manual	Consider updating the statistics at the beginning of Section 4.03.04 of the manual with findings from this report.
Work Zone Safety and Mobility Manual	Part A of Section 6.01.19 of the manual outlines the use of transverse temporary rumble strips for freeways. The department could consider more aggressive use of these devices as a part of freeway projects where lane closures or crossovers are being implemented along facilities without recurring congestion under normal operations (given the relative safety performance impacts for these facilities demonstrated in this report). For example, consider if the three-day (for consideration on any project) or fourteen-day (where they may be required) thresholds could be reduced to maximize the number of days where rumble strips are in place for these types of projects. The *Microsoft Excel tool* could be used to support this process as well as identify poorly performing stages or locations for all types of freeway projects that may benefit from this treatment.

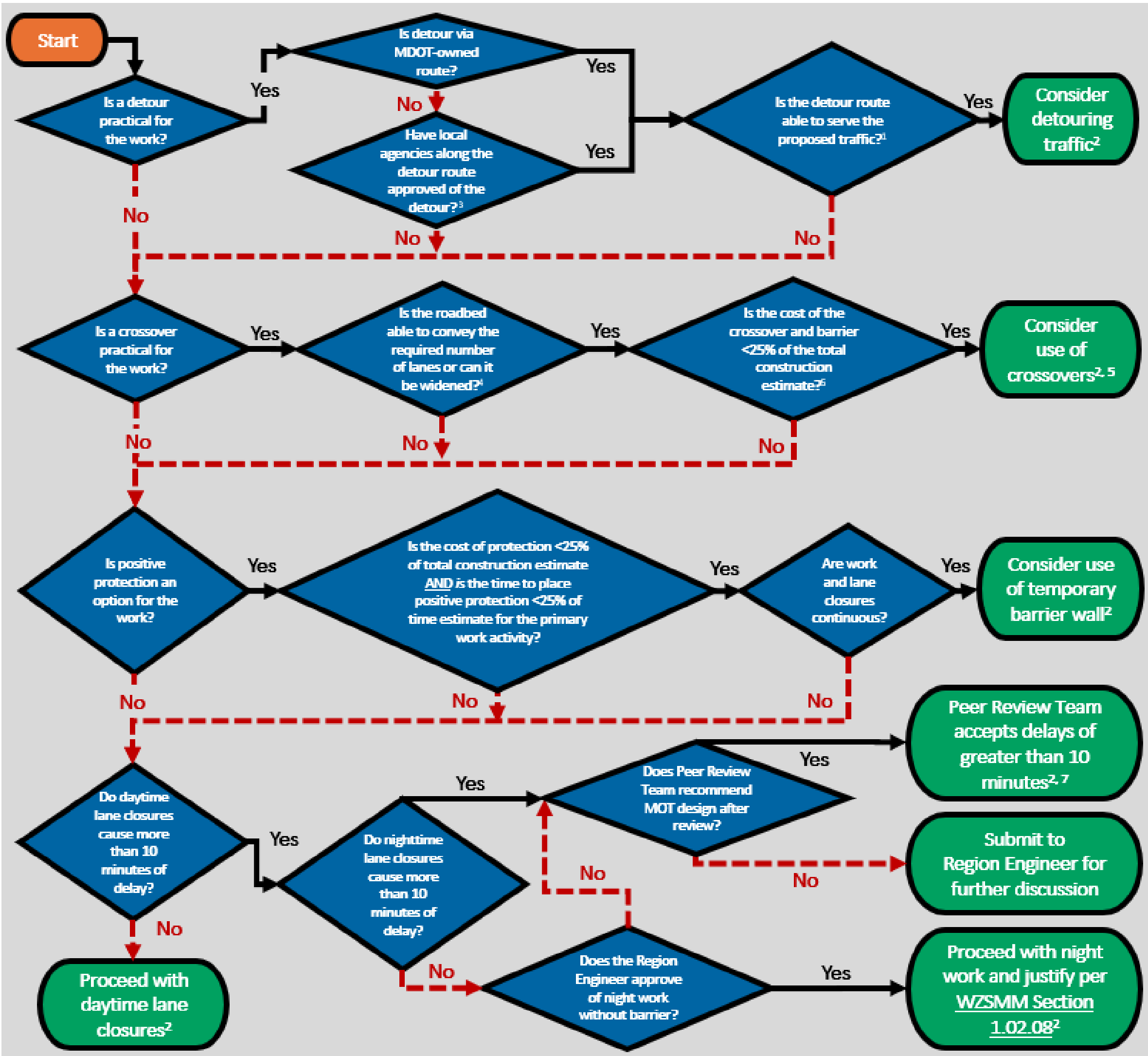
Resource	Recommendation
Work Zone Safety and Mobility Manual	Section 6.06 discusses the use of ITS devices within Michigan work zones, including guidance for scenarios where such treatments should be considered after a work zone is in place. Findings from this study can be used to expand this guidance, such as considering the use of these devices for location in scenarios where the analysis suggests diminished safety performance. The *Microsoft Excel tool* can also be used to support this process.
Work Zone Safety and Mobility Manual	Section 6.06.04 of the manual discusses the use of stopped traffic advisory systems, including the guidance that these systems should be used along corridors with a history of rear end collisions. However, this study provides evidence that freeways that do not experience recurring congestion under normal operations observed the largest relative impacts on safety performance during work operations. Consider revising this guidance to emphasize these systems can be valuable across a broad range of scenarios. The *Microsoft Excel tool* can also be used to identify projects that may benefit from this treatment.
Work Zone Safety and Mobility Manual	Part B of Section 6.06.09 provides guidance for the use of radar speed trailers, including that more devices can be added at problem areas as defined by the engineer. Consider adding guidance that recommends comparing ongoing safety performance with the SPFs presented above to identify potential problem areas. The *Microsoft Excel tool* can also be used to support this process.
Work Zone Safety and Mobility Manual	Given that House Bills 4132 and 4133 authorize MDOT to employ automated speed enforcement systems within highway work zones, findings from this report could be used to provide initial guidance for potential projects to consider. The *Microsoft Excel tool* can also be used to support this process.
Work Zone Safety and Mobility Manual	A revised *Safety & Mobility Decision Tree* is provided that maintains the existing engineering approach. The revised flowchart provides a structure that should allow for simple modification in the future. One such potential modification could include an additional note specific to the use of crossovers within the flowchart, where the current cost threshold of 25 percent of the total construction cost estimate represents an effective high-level approach for the MDOT. However, an analysis based on findings from this report could be used to determine if there are potential projects where the use of crossovers may represent a particularly effective strategy from a safety perspective compared to other MOT alternatives (such as a lane closure) despite exceeding this threshold. This analysis should incorporate a comprehensive evaluation of the entire construction influence area for each MOT alternative (as opposed to simply comparing performance within the activity area itself). The *Microsoft Excel tool* can also be used to support this process.
All Resources	Future work in this area could include research to develop similar safety analysis tools for non-freeway facilities, with a focus on both trunkline and non-trunkline arterials. This research would be particularly valuable in that it would allow agencies to develop temporary traffic control plans that maximize mobility and safety performance for non-motorized road users, as well as provide guidance to reduce conflicts between vehicles and traffic regulators.
Work Zone Safety *Fast Facts* Page	Consider updating the webpage and associated “Work Zones 101” flyer with findings from the statewide analysis.

MDOT Safety & Mobility Decision Tree

(*Recommended Revisions from OR23-022*)

Michigan Department of Transportation

PA 164 of 2023 describes requirements for closing freeways or portions of freeways. The flowchart below outlines safety considerations to assist in determining maintaining traffic design. Use of the decision tree is mandatory for all MDOT freeway projects and optional for all other roadways. The flowchart is intended to be used to evaluate MOT options and promote a culture of safety for all. It is important to recognize that the decision tree is intended to supplement (and not replace) engineering judgement. Ultimately, the decision tree should help to ensure designers consider overall safety performance, minimize night work, and emphasize the separation of vehicles and workers. Detours should be considered for all stages of the work, not just as a part of the overall project scope.



1	Designers should consider overall traffic volumes, turning movements, coordination of work, and other factors.
2	Designers should consider a range of potential temporary traffic control devices or other work zone mitigation strategies consistent with engineering judgement, including temporary rumble strips, stopped traffic advisories, radar speed trailers, police presence, enhanced night lighting, 25' maximum drum spacing, truck mounted attenuators or mobile truck barriers.
3	Reallocated funds may be offered to Local Agencies to improve detour routes.
4	Designers should consider the number of lanes necessary to maintain less than or equal to 10 minutes of delay.
5	Consider if a zipper wall should be used to accommodate peak hour flow.
6	Designers should consider alternate MOT schemes to accommodate crossovers beyond the conventional temporary barrier wall approach.
7	After assessing all reasonable mitigation measures, the peer review team accepts delays greater than 10 minutes. Mitigation recommendations to be provided by the peer review team.

Recommended MDOT Safety & Mobility Decision Tree

1.0 INTRODUCTION AND BACKGROUND

Despite the fact that highway work zones represent a required element of maintaining and improving the transportation network, the resulting changes in traffic patterns, narrowed right-of-way, and other construction activities can lead to an increased risk for traffic crashes and related injuries or fatalities [*1*]. A total of 5,128 work zone-related traffic crash fatalities occurred across the United States during the six-year period between 2017 and 2022, including 226 workers on foot [*2*]. Work zones can also represent a major cause of congestion, delay, and traveler dissatisfaction [*3*]. Approximately ten percent of congestion nationally has been estimated to be related to the presence of highway work zones, including 35 percent of congestion within rural areas [*2*]. As shown in **Figure 1**, construction or maintenance-related work zone crashes occur across the state – primarily along the interstate and arterial highway network where such work is required to effectively sustain the transportation system.

Figure 1. Michigan Work Zone Traffic Crashes (2017-2022)

1.1 Background

The federal *Work Zone Safety and Mobility* rule, initially established in 23 CFR 630 in 2004 [*4*], required that all states develop a "policy for the systematic consideration and management of work zone impacts on all federal aid highway projects across all stages of project planning, development, construction and operations". In response to the federal rule, MDOT established the *Work Zone Safety and Mobility Policy* [*5*] in 2007 which applies to all construction and maintenance work zones in the state. The processes, procedures, and guidelines to support this policy are detailed in MDOT's *Work Zone Safety and Mobility Manual* [*6*], which has been revised several times since its initial publication in order to be consistent with current best practice. The manual also outlines the department's methods to evaluate safety and mobility within highway work zones [*6*]. The primary goal of MDOT's work zone policies is to reduce crashes and manage the congestion induced by the temporary traffic control [*6*].

The 2017 increase in the state gas tax has led to additional road work throughout Michigan, which will continue to increase with the phasing in of the annual indexing increases to the state gas tax that began in 2022. Further, the continued increase in annual traffic fatalities coupled with the increasing speed limits and subsequent travel speeds on freeways and other rural trunklines throughout the state has continued to exacerbate safety and mobility concerns for work zones. With the recent addition of work zone safety attributes to the UD-10 form, the timing is essential to identify those critical work zone attributes that are related to improved (or degraded) work zone safety and/or mobility. This not only includes crashes that occur within the work zone proper, but also for crashes that occur outside of the limits of the work zone, but are still influenced by the work zone (e.g., back of queue crashes prior to the work area).

1.2 Objectives

Consistent with MDOT's commitment to the Safe System Approach [*2*], the department sponsored research project OR23-022 (*Optimizing Work Zone Conditions to Maximize Safety and Mobility*) to identify the critical attributes that influence safety and mobility within Michigan work zones. MDOT and other agencies also desire a method to measure work zone safety and mobility performance, with consideration given to cost, to ensure that scarce transportation funds are spent wisely on the optimal strategies. The outcomes of the research include a synthesis of prior research and best practices used by other agencies, a benchmark of Michigan's safety performance versus the national experience, methods for measuring the effectiveness of work zone configurations, recommended strategies to mitigate work zone crashes and conditions for application, and guidance for optimizing safety and mobility for work zones, including recommendations for MDOT's *Work Zone Safety and Mobility Manual* [*6*]. To those ends, the specific objectives of this research include:

1. Synthesize nationwide best practices for optimizing work zone safety and mobility.
2. Assess the safety performance benefits of various work zone designs. In doing so,
    a. Assess crash frequency and crash rate for each area of the work zone.
    b. Identify optimal configurations and mitigation strategies to minimize crash risk.
3. Determine performance measures to assess the effectiveness of work zone designs
4. Recommend strategies to mitigate work zone crashes and conditions for application
5. Develop guidelines for optimizing safety and mobility for work zones, including recommendations for the MDOT's *Work Zone Safety and Mobility Manual* [*6*].

These research objectives were completed via the process outlined in **Figure 2**, where the project began with a review of the literature as well as the identification of relevant existing MDOT policies and guidance (**Chapter 2**). Next, a statewide analysis of historical work zone crash data was conducted in order to quantify recent trends with respect to work zone safety both within Michigan and around the country (**Chapter 3**). Historical models were also developed of 25 freeway work zones across the state of Michigan in order to evaluate the safety and mobility impacts of implementing temporary traffic control to complete long-term construction projects (**Chapter 4**). Findings obtained from **Chapters 2-4** were aggregated to support the development of recommendations to optimize safety and mobility within Michigan work zones (**Chapter 5**).

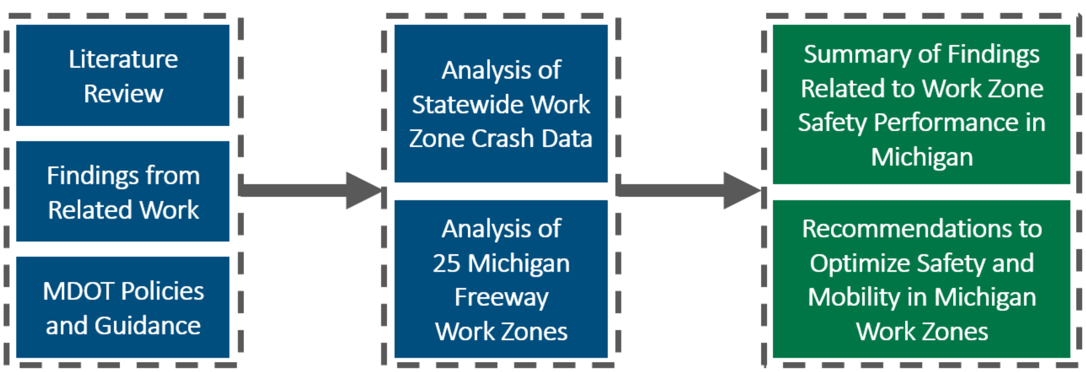


Figure 2. Overview of Research Methodology

2.0 LITERATURE REVIEW

The project initiated with a comprehensive literature review to identify the state-of-the-art knowledge base related to effective strategies for optimizing highway work zone safety and mobility. This was completed by conducting a search of project reports from agencies including state departments of transportation, the Federal Highway Administration (FHWA), and the National Cooperative Highway Research Program (NCHRP), as well as a review of relevant articles from transportation engineering journals. The Transportation Research Board's (TRB) Transportation Research International Documentation (TRID) bibliographical database and other relevant search engines were also utilized to identify relevant publications. The literature review represented the first stage of developing a synthesis of best practices for work zone safety and mobility where the primary objectives were to:

- Identify nationwide best practices for optimizing work zone safety and mobility.
- Determine how agencies typically assess work zone safety performance, particularly with respect to specific crash types.
- Identify cost effective work zone configurations and mitigation strategies.
- Identify performance measures to assess the effectiveness of work zone designs.

The subsections below provide a topical summary of the literature reviewed as a part of this effort, including safety and mobility performance measures (**Section 2.1**), mitigation strategies for work zones (**Section 2.2**), a review of MDOT's existing policies and guidance (**Section 2.3**).

2.1 Overview of Work Zone Safety and Mobility Performance Measures

The federal *Work Zone Safety and Mobility* rule, initially established in 23 CFR 630 in 2004 [*5*], required that all states develop a "policy for the systematic consideration and management of work zone impacts on all federal aid highway projects across all stages of project planning, development, construction and operations". Key guidance or research efforts specific to managing these potential impacts are summarized in **Table 1**, and further detail can be found in **Section 2.1.1** (safety performance measures) and **Section 2.1.2** (mobility performance measures).

Table 1. Key Resources Related to Best Practices for Work Zone Safety and Mobility

Reference	Summary
FHWA's *Developing and Implementing Transportation Management Plans for Work Zones* (2005) [*7*]	Guidance document developed by the FHWA subsequent to the publication of the federal rule that outlines transportation management plans and associated work zone management strategies.
FHWA's *Work Zone Impacts Assessment: An Approach to Assess and Manage Work Zone Safety and Mobility Impacts of Road Projects* (2006) [*8*]	Guidance document developed by the FHWA subsequent to the publication of the federal rule that assists agencies with development or revision of policies, procedures, and processes related to maintaining work zone safety and mobility.
NCHRP's *Best Practices in Work Zone Assessment, Data Collection, and Performance Evaluation* (2010) [*9*]	The document summarizes a domestic scan of current practice related to work zone assessment, data collection, and performance measures. The scan team interviewed 15 roadway agencies and developed a series of recommendations based on the findings.
FHWA's *Work Zone Road User Costs Concepts and Applications Document* (2011) [*10*]	Released in 2011, this document provides a synthesis of road user cost practices and tools. It also established a framework for work zone road user cost analysis and provides guidance on road user cost applications.
MDOT's *Balancing the Costs of Mobility Investments in Work Zones* (2015) [*11*]	MDOT research that included a state agency survey, a motorist survey, as well as the collection and analysis of work zone safety, operations, and cost data.

2.1.1 Work Zone Safety Performance Measures

Given that construction or maintenance activities must often be performed while road users are present along highway facilities, work zones have the potential to impact safety performance in a number of ways [*12*]:

- The presence of workers, equipment, construction materials, traffic barriers, and traffic control devices results in more objects in close proximity to the traveled way than conditions that existed prior to the implementation of the work zone.
- Lane shifts or closures often require vehicles to complete a change in travel path that may not be well understood by all drivers, despite the presence of traffic control devices.
- Lane closures or other modifications to the originally intended design of the roadway may result in capacity reductions that can lead to the potential for back-of-queue collisions.

Consistent with these concerns, prior research has generally demonstrated that safety performance degrades within work zones when compared to the safety performance experienced during normal operations [*13*]. The safety performance of work zones is influenced by the overall design, temporary traffic control, work activity, and related roadway or traffic characteristics [*14*]. While there is a broad library of prior research related to various aspects of work zone safety, selected foundational efforts related to the evaluation of work zone safety performance measures are summarized in **Table 2** where more detailed information can be obtained beyond this summary.

Table 2. Key Resources Related to Work Zone Safety Performance Assessment

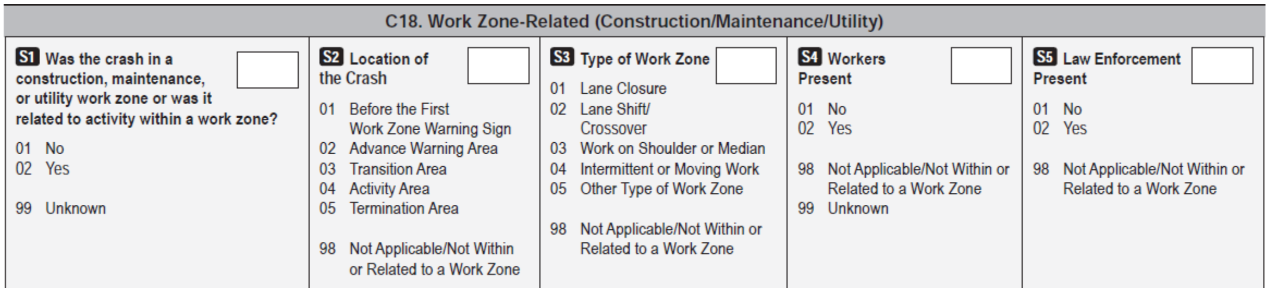
Reference	Summary
NCHRP Report 627 *Traffic Safety Evaluation of Nighttime and Daytime Work Zones* (2008) [*13*]	Research provided work zone crash rates, identified management best practices, and made recommendations to improve collection of work zone crash data.
AASHTO *Highway Safety Manual* (2010) [*14*]	National manual that provides information and methodologies for quantifying safety performance along existing or proposed roadways, including tools that are specific to evaluating work zone safety performance.
NCHRP Research Report 869 *Estimating the Safety Effects of Work Zone Characteristics and Countermeasures: A Guidebook* (2018) [*13*]	Guidebook intended to assist practitioners with the safety performance impacts of decisions related work zone temporary traffic control, including methods to evaluate the impact of specific mitigation strategies.
IDOT's *Work Zone Safety Performance on Illinois State Routes* (2020) [*15*]	Research sponsored by IDOT focused on the analysis of work zone traffic crash data, including the development of aggregate crashes, SPFs and CMFs. The work also included the identification of existing gaps in work zone safety data.
FHWA's *Development and Application of Work Zone Crash Modification Factors – 2nd Edition* (2020) [*16*]	Guidance document developed by the FHWA that provides a procedure for evaluating highway work zone countermeasures via existing crash modification factors as well as procedures for the development of future work zone crash modification factors. It should be noted that this work included a survey of state agency with respect to work zone safety analysis and crash modification factors.
FHWA's *Data-Driven Approaches to Improve Work Zone Safety* (2022) [*17*]	Guidance document that provides an overview of decision-support tools specific to the planning and evaluation of work zone safety performance. The document includes policies and guidelines, decision trees and flowcharts, and a series of predictive tools to assess the cost-effectiveness of mitigation strategies.

There are a number of ways that practitioners could employ specific safety performance metrics as a part of evaluating work zone planning and design decisions, including [*12*]:

- Quantify the potential benefits of reducing the duration of specific work activities (and therefore have the ability to evaluate the value of accelerated contract incentives).
- Estimate the expected safety performance impacts of specific countermeasures (such as the inclusion of temporary rumble strips) included in transportation management plans (TMP).
- Evaluate the safety performance of impacts of various work zone design decisions (such as reduced lane widths or shoulder closures) to compare potential design alternatives.

Despite the potential benefits of conducting such data-driven safety performance analyses, it is critical to recognize that the evaluation of work zone-related crash data has been described in FHWA guidance as "an area of considerable nuance" [*17*]. These crash analyses fundamentally rely on the availability of high-quality data specific to roadway characteristics, traffic volumes, and work zone temporary traffic control [*17*]. However, work zone activity data collected by agencies are often intended for real-time work zone management and may require subsequent review to integrate into safety performance analyses [*17*]. These data may also include only limited information as to the type of work (e.g. shoulder closure or lane closure) but not details related to temporary traffic control or other factors that potentially influence safety [*17*]. Similarly, the traffic volumes serviced by roadway facilities during work activities may vary from annual estimates and this information is often not directly collected for use in subsequent crash evaluations [*17*].

The ability to identify work zone-related crashes is also paramount to conducting appropriate safety performance analyses, defined in the Model Minimum Uniform Crash Criteria (MMUCC) as a "crash that occurs in or related to a construction, maintenance, or utility work zone, whether or not workers were actually present at the time of the crash" [*18*]. It is also important to recognize that this can also include collisions where the first harmful event occurred upstream of the first warning sign [*18*]. Model work zone fields from the MMUCC are presented in **Figure 3** that can be used to obtain detailed information related to the location of each crash (as shown in **Figure 4**), the type of work zone, the presence of workers, or the presence of law enforcement. The Michigan State Police revised the Michigan UD-10 crash report form in 2016 to include new data elements specific to traffic crashes occurring in work zones in a manner similar to the MMUCC.



C18. Work Zone-Related (Construction/Maintenance/Utility)

S1 Was the crash in a construction, maintenance, or utility work zone or was it related to activity within a work zone?	S2 Location of the Crash	S3 Type of Work Zone	S4 Workers Present	S5 Law Enforcement Present
01 No	01 Before the First Work Zone Warning Sign	01 Lane Closure	01 No	01 No
02 Yes	02 Advance Warning Area	02 Lane Shift/ Crossover	02 Yes	02 Yes
99 Unknown	03 Transition Area	03 Work on Shoulder or Median	98 Not Applicable/Not Within or Related to a Work Zone	98 Not Applicable/Not Within or Related to a Work Zone
	04 Activity Area	04 Intermittent or Moving Work	99 Unknown	
	05 Termination Area	05 Other Type of Work Zone		
	98 Not Applicable/Not Within or Related to a Work Zone	98 Not Applicable/Not Within or Related to a Work Zone		

Figure 3. Model Work Zone Fields from MMUCC [*18*]

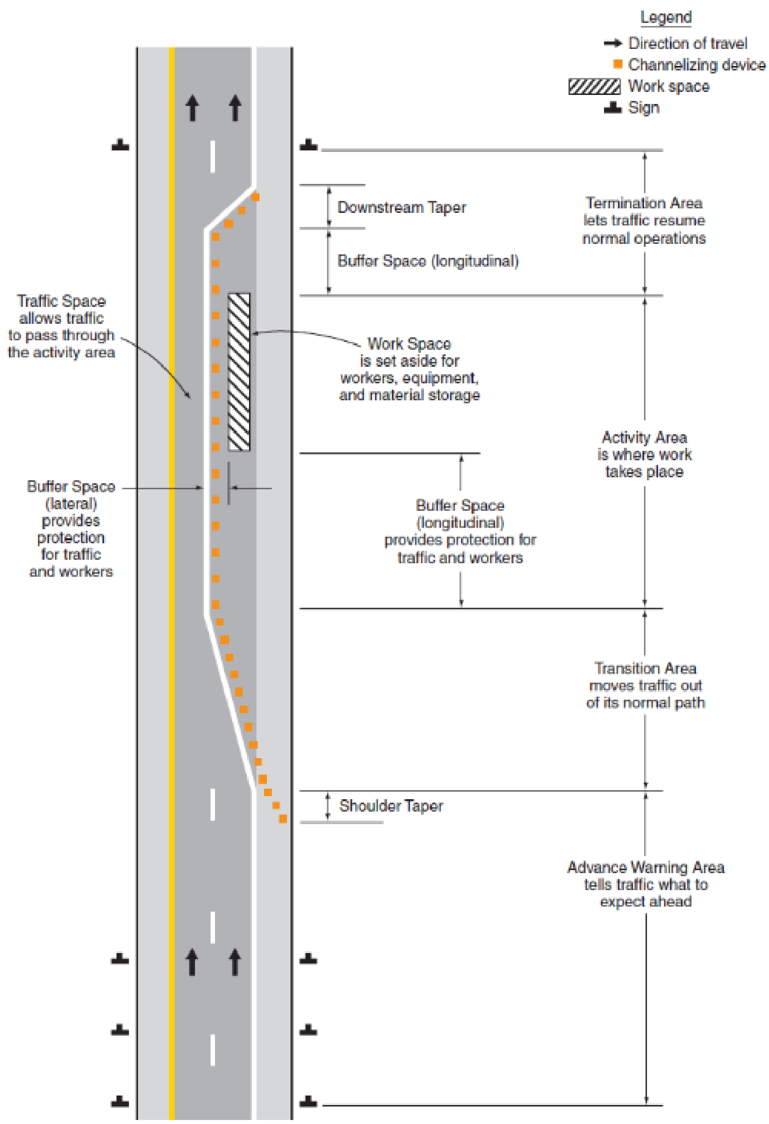


Figure 4. Component Parts of a Temporary Traffic Control Zone [*19*]

The American Association of State Highway and Transportation Officials (AASHTO) *Highway Safety Manual* (HSM) [*14*] outlines a framework for evaluating the safety performance of roadway facilities, including methods to estimate the expected safety performance specific to work zones. While there are a number of potential methodologies identified with the references included in **Table 2**, work zone safety performance is typically assessed via some combination of safety performance functions (SPFs) and crash modification factors (CMFs).

SPFs are mathematical models that can be used to predict crash frequencies (N_{spf}) based on a series of explanatory variables, including roadway, traffic, or work zone characteristics. For example, prior research [*20*] has suggested using two SPFs that include directional annual average daily traffic ($AADT$, in vehicles per day), segment length (L, in miles), and the duration of the analysis period (D, in days) to compare the difference in predicted crash frequencies for a roadway under normal conditions (**Equation 1**) and with a work zone present (**Equation 2**):

$N_{spf} = e^{-17.50} \times AADT^{1.31} \times L^{0.63} \times D^{0.99}$. **(Eq. 1 – non-work zone condition)**

$N_{spf} = e^{-17.50} \times AADT^{1.33} \times L^{0.61} \times D^{1.23}$ **(Eq. 2 – work zone condition)**

Research sponsored by MDOT in 2015 [*11*] included the development of SPFs based on data from historical Michigan work zones, including the comparison of specific closure types (shoulder, single lane, multilane, and lane shifts), shown in **Figure 5**.

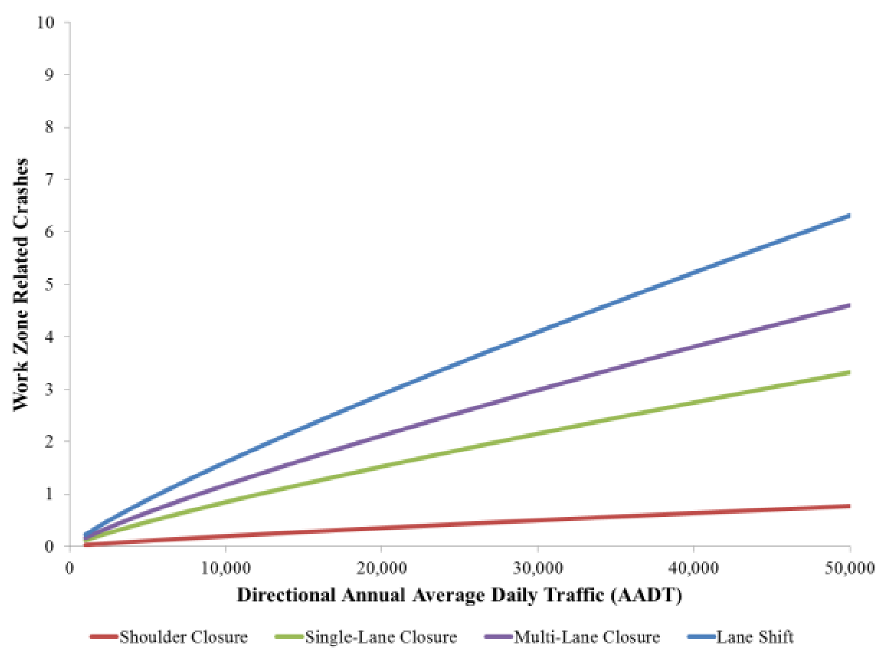


Figure 5. Michigan-Specific Work Zone SPFs from Savolainen et al. [*11*]

CMFs, or multiplicative factors that represent the change in safety performance based on the presence or absence of a specific condition [*17, 21*], have also been developed to estimate expected crashes for a number of work zone conditions. For example, prior work [*20*] has suggested CMFs to evaluate the expected change in crash frequency as the length (CMF_{length}) or duration ($CMF_{duration}$) the work zone increases beyond default values. These CMFs are presented in **Equations 3 and 4** below and shown visually in **Figure 6**.

$$CMF_{length} = 1.0 + \frac{(\%\ increase\ in\ length\ in\ miles \times 0.67)}{100} \quad \textbf{(Eq. 3)}$$

$$CMF_{duration} = 1.0 + \frac{(\%\ increase\ in\ duration\ from\ 16\ days \times 1.11)}{100} \quad \textbf{(Eq. 4)}$$

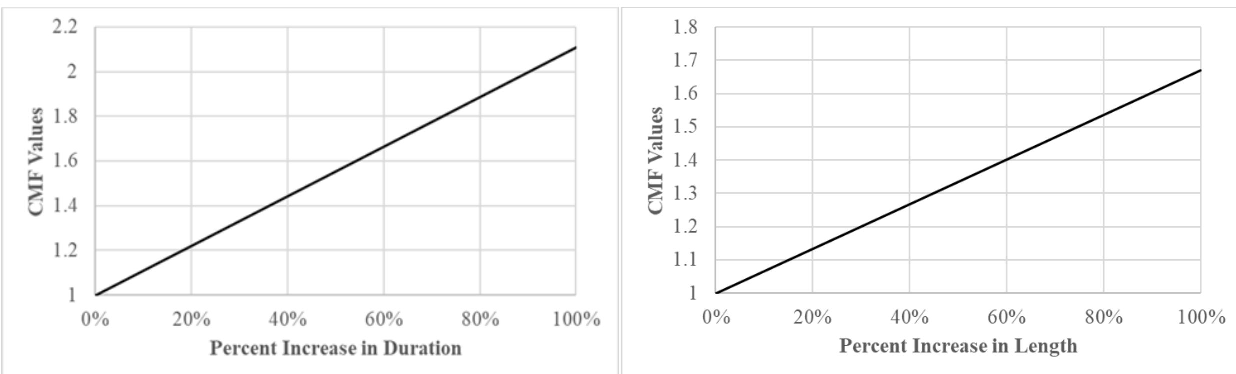


Figure 6. Crash Modification Functions for Work Zone Duration and Length [*15*]

However, the availability of reliable CMFs specific to highway work zones remains fairly limited in comparison to the vast library available to evaluate conditions that are not related to work zones [*16*]. While the FHWA's *Development and Application of Work Zone Crash Modification Factors* [*16*] provides procedures and guidance to develop new work zone CMFs, NCHRP Research Report 869 *Estimating the Safety Effects of Work Zone Characteristics and Countermeasures: A Guidebook* (2018) [*12*] has also suggested considering CMFs that were not developed with work zone-specific data if there is no obvious reason why it would not be applicable to a work zone scenario. For example, this could include evaluating the use of temporary traffic control devices (such as speed feedback displays), geometric modifications (such as changing median widths or temporarily removing exclusive turn lanes), or temporarily removing non-motorized facilities (such as sidewalks or bicycle lanes).

2.1.2 Work Zone Mobility Performance Measures

The evaluation of work zone operational performance is a complex topic that includes an extensive body of prior research specific to the mobility impacts of work zones and related road user costs [*11, 22-50*]. Within Michigan, MDOT's *Work Zone Safety and Mobility Manual* [*6*] details the process to conduct mobility analyses required for all projects based on the level of significance of the work. Research conducted in Michigan in 2015 included the evaluation of operational data collected both in the field at active work zones as well as historical travel time and speed data acquired via the Regional Integration Transportation Information System [*11*].

While there is a broad library of prior research related to various aspects of work zone mobility impacts, selected foundational efforts related to the evaluation of work zone operational performance measures are summarized in **Table 3** where more detailed information can be obtained beyond the summary included within this review.

Table 3. Key Resources Related to Work Zone Operational Performance Measurement

Reference	Summary
Idaho DOT's *Synthesis of Research on Work Zone Delays and Simplified Application of QuickZone Analysis Tool* (2010) [*44*]	Research conducted by the Idaho Department of Transportation that synthesized prior work related to work zone operational analysis and methods to employ FHWA's QuickZone tool.
FHWA's *A Primer on Work Zone Safety and Mobility Performance Measurement* (2011) [*45*]	While the primer includes information related to exposure and safety performance measures, the document provides both procedures and methods to collect data to support work zone operational analyses.
SWZDI's *Highway Work Zone Capacity Estimation Using Field Data from Kansas* (2015) [*46*]	Research conducted in Kansas that estimated the capacity of rural highway work zones in order to provide operational performance guidance for practitioners specific to rural facilities.
Delaware DOT's *Determining Work Zone Lane Capacities along Multilane Signalized Corridors* (2017) [*47*]	Research sponsored by the Delaware Department of Transportation that collected data from highway work zones to develop a novel methodology to evaluate work zone capacity based on speed-flow-density relationships for multilane signalized corridors.
SWZDI's *Understanding the Impacts of Work Zone Activities on Traffic Flow Characteristics* (2018) [*48*]	Research conducted in Missouri that evaluated field data from work zones to determine how a variety of work activities impact speed-flow-density relationships as well as develop capacity reduction factors.
FHWA's *Auditing Work Zone Mobility Using Probe Vehicle Data* (2020) [*49*]	FHWA guidance document that outlines the use of work zone mobility audits conducted via probe vehicle data to assess operational performance.
Highway Capacity Manual – 7th Edition (2022) [*50*]	The manual includes guidance and procedures to assess capacity and the level of service for highway facilities, including considering the impacts of temporary conditions (including work zones).

2.2 Mitigation Strategies for Work Zones

Roadway agencies have employed a broad range of mitigation strategies to minimize the safety and mobility impacts of work zones, including both strategies that are proven (or prior research and experience has demonstrated its effectiveness) or emerging (or treatments that agencies have experimented with that may not be included in the MUTCD [*19*]). **Sections 2.2.1-2.2.4** outline the safety and mobility research specific to common and emerging mitigation strategies, with a focus on the availability of existing analytical tools (such as SPFs or CMFs) to quantify potential work zone impacts. Due to the fact that many of these strategies have entire documents dedicated to their application, references are provided where more detailed information can be obtained. For example, more details related to specific work zone safety strategies can be found in the FHWA's *Toolbox of Low-Cost Work Zone Management Strategies* [*51*] or FHWA's *Developing and Implementing Transportation Management Plans for Work Zones* [*7*]. Within Michigan, MDOT's *Work Zone Safety and Mobility Manual* [*6*] provides a detailed list of strategies and guidance to mitigate concerns related to the safety and mobility impacts.

2.2.1 General Strategies

The strategies outlined in **Sections 2.2.1.1-2.2.1.7** include fundamental concepts of work zone TMP development. These concepts can also represent components of more complex strategies (e.g. a portable changeable message sign included in a queue warning system).

2.2.1.1 Strategies Related to Work Zone Design, Closure Type, Length, or Duration

There are a number of fundamental analytical safety tools for evaluating work zone safety performance beyond the research conducted by Khattak and Council from 2002 [*20*] that is included in the HSM (and summarized in **Section 2.1.1**). NCHRP Report 627 *Traffic Safety Evaluation of Nighttime and Daytime Work Zones* (2008) [*13*] compared the performance of daytime and nighttime work zones across a range of scenarios (including work activity and the presence of a lane closure). A total of 72 different CMFs are included in FHWA's *CMF Clearinghouse* [*21*] based on this work that compare the safety performance of various work zone scenarios to normal conditions with no work zone present, ranging from 0.94 (for injury crashes where no work activity or lane closure were present) to 2.26 (for nighttime injury crashes with active work and no lane closure). Ozturk et al. [*52*] also evaluated the safety performance impacts of 60 long-term work zones, including the development of four CMFs ranging between 1.078 and 1.214 depending on the time of work (day or night) and injury severity.

There are also a number of studies that have evaluated specific aspects of work zone safety performance and design strategies [*11-15, 17, 18, 21, 53-109*]. Research that has led to the development of distinct tools to evaluate safety performance impacts are discussed in more detail below:

- See et al. [*55*] evaluated the safety performance impacts of implementing a left-hand merge combined with a downstream lane shift (otherwise known as an “Iowa Weave”) compared to a conventional right-hand lane closure. CMFs of 0.54 for all crashes and 2.24 for fatal and injury crashes were developed as a part of the study when considering the “Iowa Weave” approach.
- The evaluation of the “Super 70” I-70 reconstruction project in Indianapolis conducted by Tarko et al. [*56*] included the development of CMFs for evaluating the safety benefits of increasing the outside shoulder width by one foot (0.948) and inside shoulder width by one foot (0.97).
- Chen and Tarko [*64*] developed negative binomial regression models in 2014 that employed a monthly structure (as opposed to annual crash frequencies) to consider temporal effects. Additionally, the work demonstrated that detour signage, lane shifts, and lane splits impact work zone safety performance.
- Research conducted in Missouri [*69, 70*] included the development of a crash prediction software tool based on a series of SPFs specific to work zones implemented in a number of roadway scenarios. The crash prediction tool can be used to compare safety performance across potential design alternatives. The explanatory variables beyond traffic volume included within each model varied by the site type under evaluation (e.g. number of ramps for freeways or number of signals for non-freeways).
- La Torre et al. [*71*] employed the Empirical Bayes (EB) method to evaluate the safety performance impacts of implementing work zones along freeways in Italy, including the development of a broad range of CMFs specific to various types of closures.

2.2.1.2 Portable Changeable Message Signs (PCMS)

The use of portable changeable message signs (PCMS) in work zones represents a common strategy employed by all roadway agencies in some aspect of temporary traffic control [*51*]. PCMS applications in work zones range from conventional static messaging to drivers (such as warning of downstream closures) to the integration with intelligent transportation systems (ITS) as a part of more complex mitigation strategies (such as a queue warning system) [*51*]. The use of PCMS in work zone applications has been evaluated in a number of studies, typically focused on reductions in operating speed [*51*]. This prior work has generally suggested that the use of PCMS has been associated with speed reductions between approximately two to five miles per hour [*110-112*]. Crash prediction models developed by Tarko et al. [*56*] using data from the I-70 reconstruction in Indianapolis can be used to estimate risk over 30-minute intervals and the researchers suggested using changeable message signs to convey real-time risk to drivers. Research conducted by Chen and Tarko [*113*] suggested that the use of changeable message signs to display information related to enforcement improved the effectiveness of work zone law enforcement. It should be noted that permanent changeable message signs also have a number of potential work zone applications [*51*] that have proven to be effective in prior research [*112*].

2.2.1.3 Positive Protection Barriers

Portable traffic barriers are another fundamental work zone safety strategy intended to "physically prevent vehicles and pedestrians traveling through the work zones from entering space occupied by workers, equipment, materials or roadside hazards" [*114*]. This includes a variety of barriers that may be used depending on the work zone scenario, including portable concrete barriers [*115*], ballast-filled barriers typically filled with sand or water [*116*], portable steel barriers [*117*], mobile barrier trailers or moveable barrier systems [*118*], and truck-mounted attenuators [*119*]. There are a number of resources available that provide detailed guidance specific to the use of positive protection in highway work zones [*120-125*]. Agencies have also used a number of data-driven procedures to support decisions related to positive protection in highway work zones [*18*], such as the process specified by the Virginia Department of Transportation [*126*] that incorporates distinct safety analysis tools.

2.2.1.4 Work Vehicle and Work Zone Lighting

Work vehicle lighting, defined within the MUTCD as "high-intensity rotating, flashing, oscillating or strobe lights" [*19*], represents a core component of work zone temporary traffic control. While NCHRP Report 624: *Selection and Application of Warning Lights on Roadway Operations Equipment* provides detailed information on the selection and application of warning lights [*127*], roadway agencies have also experimented with a number of innovative strategies such as the use of blue lights on paving equipment (**Figure 7**) or green warning lights on truck mounted attenuators (**Figure 8**).

Figure 7. Example of Blue Lights on Paving Equipment [*128*]

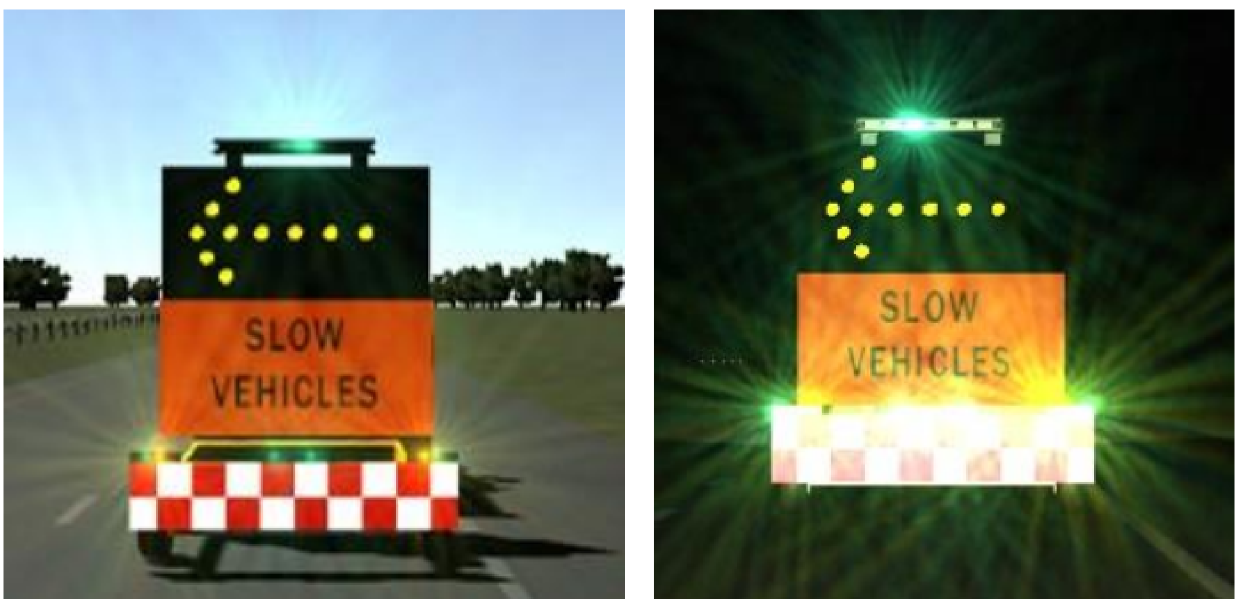


Figure 8. Example of Green Lights on Truck Mounted Attenuators [*129*]

Work zone lighting is another strategy employed by roadway agencies to improve safety for road workers [*49*]. While there are several national resources for the use of work zone lighting [*130-133*], there are no CMFs currently available. It is important to note that work zone lighting is not intended as temporary illumination for the roadway environment [*130*] and it is also critical to control the glare such that driver visibility is not impacted [*134*]. There are a number of common approaches to temporary lighting for work zones, including [*131*]:

- Portable light plant towards (or mast arms with luminaires at various heights)
- Balloon lighting systems (shown in **Figure 9**)
- Conventional roadway luminaires that are mounted on temporary poles
- Factory-installed lighting devices included on specific work equipment

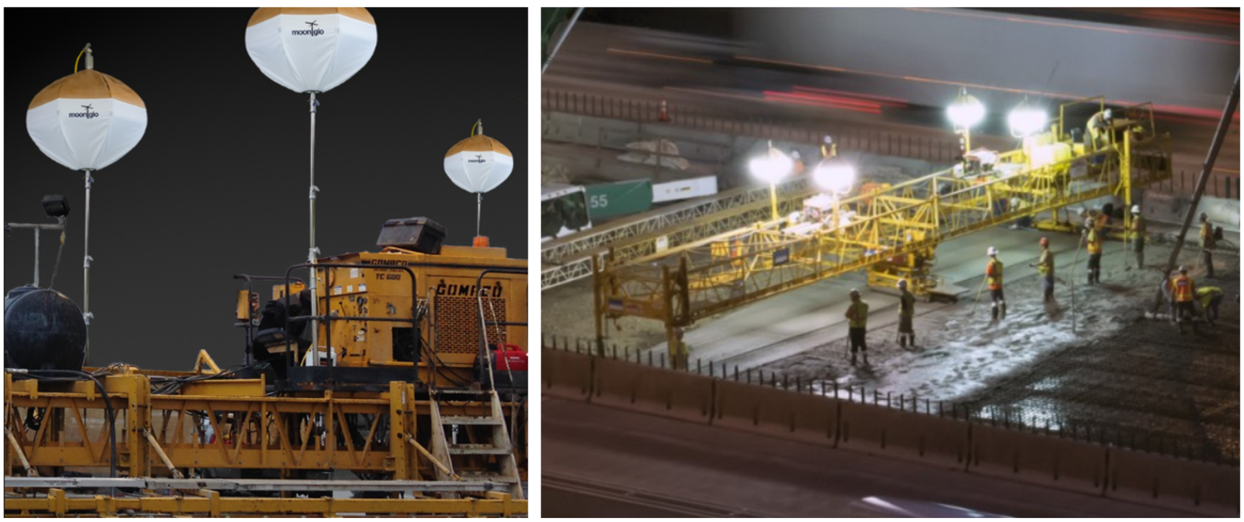


Figure 9. Example of Balloon Lighting System [*135*]

<u>2.2.1.5 Channelizing Device Strategies</u>

Roadway agencies have also employed several mitigation strategies related to channelizing devices [*52*]. This has included evaluating the potential use of drum enhancements (such as the use of warning lights added to drums or other channelizing devices [*136-139*]) as well as the use of systems that move or retrieve devices to reduce exposure for workers [*51*]. It should be noted that there are currently no CMFs to evaluate the impacts of these strategies. Additionally, research conducted in Michigan [138] recommended that tangible and intangible costs associated with warning lights on drums outweighed any safety benefits associated with the marginally increased luminance (and MDOT has subsequently discontinued this approach).

2.2.1.6 Pedestrian and Bicycle Accommodation

While the MUTCD does provide basic criteria for the accommodation of non-motorized road users in work zones [*19*], the consideration of work zone impacts on pedestrians and bicyclists remains an area where there is only limited quantitative research [*140*]. However, it should be noted that there are a number of national resources that provide best practices and qualitative guidance for pedestrian and bicycle accommodation [*140-143*]. Prior research has also suggested the use of CMFs for removing crosswalks or bicycle lanes developed using non-work zone data when considering temporarily removing these features as a part of a work zone design [*12*].

2.2.1.7 Law Enforcement Strategies

The use of law enforcement in work zones represents a fundamental approach to reduce speeding, speed variability, as well as other potential undesirable driver behavior [*51*]. Law enforcement in work zones typically involves stationary enforcement, circulating enforcement, or automated enforcement strategies [*144*]. It is important to recognize that all state highway agencies must have a policy in place regarding the use of law enforcement in work zones due to federal regulations [*145*], shown in **Figure 10**.

Uniformed Law Enforcement Policy in Work Zones
23 CFR Part 630 Subpart K 630.1106 (c)

Each agency, in partnership with the FHWA, shall develop a policy addressing the use of uniformed law enforcement on Federal-aid highway projects. The policy may consist of processes, procedures, and/or guidance. The processes, procedures, and/or guidance should address the following:

(1) Basic interagency agreements between the highway agency and appropriate law enforcement agencies to address work zone enforcement needs;
(2) Interaction between highway and law-enforcement agency during project planning and development;
(3) Conditions where law enforcement involvement in work zone traffic control may be needed or beneficial, and criteria to determine the project-specific need for law enforcement;
(4) General nature of law enforcement services to be provided, and procedures to determine project-specific services;
(5) Appropriate work zone safety and mobility training for the officers, consistent with the training requirements in 23 CFR 630.1008(d);
(6) Procedures for interagency and project-level communications between highway agency and law enforcement personnel; and
(7) Reimbursement agreements for law enforcement service.

Figure 10. Uniformed Law Enforcement Policy in Work Zones (*23 CFR Part 630*) [*145*]

Given that the use of law enforcement in work zones is employed by all roadway agencies, there are a number of national resources that provide guidance and information related to law enforcement strategies specific to highway work zones [*144-147*]. This includes the use of automated speed enforcement systems, which typically consist of traffic cameras, photo enforcement, or other ITS intended to enforce work zone speed limits [*148-151*]. Several studies have evaluated the safety performance impacts of various law enforcement strategies specific to highway work zones [*113, 145, 148*]. Chen and Tarko [*113*] used work zone data from Indiana to develop a CMF of 0.585 for use of police enforcement. Research conducted by Ullman et al [*145*] in 2013 provided guidance for the cost-effective use of static law enforcement in work zones based on traffic volume. While there are no work zone-specific CMFs available for the use of automated speed enforcement, prior research has suggested using a value of 0.83 developed for non-work zone conditions [*12*].

2.2.2 Traffic Regulation Strategies

Traffic regulation strategies represent a range of approaches used by roadway agencies to regulate vehicles through a work zone in a manner that improves safety performance [*51*]. These strategies are generally implemented to mitigate concerns for specific work zone scenarios, such as rolling roadblocks to perform overhead work or automated flagger assistance devices for a single lane serving bidirectional traffic [*51*].

2.2.2.1 Rolling Roadblocks

Rolling roadblocks (which are also referred to as pacing operations, rolling blocks, or traffic pacing depending on the roadway agency) are a common traffic regulation strategy that allow for short-term work by temporarily slowing or stopping upstream traffic [*51*]. While roadway agencies have employed rolling roadblocks effectively for specific work types to reduce worker exposure, it should be noted that there is a lack of quantitative research to determine performance measures. However, national guidance is available based on lessons learned from roadway agencies around the country [*152, 153*].

2.2.2.2 Alternating One-Way Work Zone Strategies

Roadway agencies have employed a number of strategies to supplement or replace flaggers for work zone scenarios where lane closures result in alternating one-way traffic flow, including pilot car operations, portable temporary traffic signals, wait time display systems, automated flagger assistance devices (AFADs), and driveway assistance devices (DADs).

Pilot car operations are a common mitigation strategy employed by roadway agencies to lead drivers through complex one-way work zones [*154*]. While quantitative research specific to the use of pilot car operations is limited, state agencies have developed guidance when considering the use of pilot cars to accommodate drivers in work zones where crossroads, lane changes, work equipment, or other potential obstacles may be present [*154-156*].

Portable traffic signals have a variety of potential work zone applications but are commonly used as a part of traffic regulating alternating one-way traffic [*51*]. These devices have often been used within long-term rural work zones where the closure is between 400 and 1,200 feet [*157*] in order to reduce the exposure of flaggers to traffic [*158*]. While prior research has evaluated the use of portable traffic signals in a variety of design scenarios to provide guidance for roadway agencies [*157-160*], it should be noted that there are currently no CMFs available.

Roadway agencies have also experimented with the use of several wait time display systems (**Figure 11**) as a part of regulating traffic for alternating one-way work zone scenarios [*51*] when considerable delays may occur. It should be noted that these systems may not be covered by the current MUTCD and can require a request to experiment [*161*]. There is only limited experience with these devices and there remains a need for more qualitative research to determine their effectiveness as well as scenarios where they should be considered for implementation.

Figure 11. Example of Wait Time Display System with Portable Traffic Signal [*162*]

Conversely, AFADs (**Figure 12**) represent a common approach to remove the need for flaggers within the traveled way for work zones with alternating one-way operations [*51*]. While there are no CMFs available specific to AFADs, state agencies have conducted a number of field studies to provide guidance for the effective application of these devices [*163-168*].

Figure 12. Examples of Automated Flagger Assistance Devices [*169*]

More recently, agencies have experimented with the use of DADs (**Figure 13**) to assist drivers with safely entering one-lane work zones with alternating one-way traffic control from driveways or minor intersections [*170*]. It should be noted that these systems remain experimental and require a formal request to experiment with the FHWA before deployment in the field [*161*]. However, research conducted in Michigan in 2022 [*170*] included optimistic initial findings and recommended that DADs should continue to be evaluated on an experimental basis.

Figure 13. Example of Driveway Assistance Device [*171*]

2.2.2.3 Lane Merging Strategies

Merging operations related to work zone lane closures represent a critical consideration for maintaining safety and mobility, especially in light of the fact that this can result in relatively large speed differentials and the potential for aggressive driving behavior [*172*]. Roadway agencies have evaluated a range of early or late merging strategies (**Figure 14**) via both static and dynamic traffic control. Given the level of importance associated with implementing effective merging strategies, there is a broad range of prior research and guidance available in the literature [*172-188*].

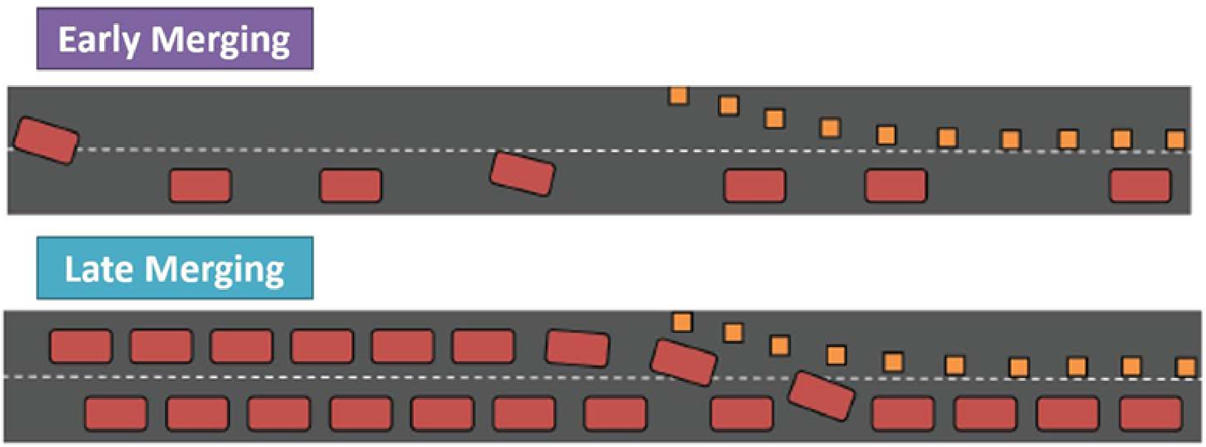


Figure 14. Conceptual Diagram of Early vs. Late Merging Strategies [*172*]

2.2.2.4 Temporary Ramp Closures, Metering, or Other Modifications

The temporary modification, closure, or metering of limited access freeway ramps are common strategies used by roadway agencies to effectively implement work zones along these facilities [*51, 189, 190*]. Temporary ramp closures can help to mitigate safety and mobility impacts by forcing vehicles to alternate routes or limiting the need for complex temporary traffic control [*189*]. Temporary ramp metering (**Figure 15**) can be used to improve merging operations and reduce the risk for potential spillover to the surrounding network [*190*]. It may also be necessary to modify other elements of ramp design, such as changes in acceleration or deceleration lane lengths. While there are not work zone-specific CMFs for these modifications, prior research has suggested the use of CMFs developed using non-work zone data [*12*].

Figure 15. Example of Work Zone Temporary Ramp Meter [*191*]

2.2.2.5 Truck Lane Restrictions, Detours, or Truck-Only Routes

Roadway agencies have also employed a range of truck lane restrictions, truck-specific detours, or truck-only routes to mitigate concerns specific to accommodating these large vehicles through highway work zones [*51*]. While there are no CMFs available for these strategies, national guidance is available to assist roadway agencies towards mitigating the safety and mobility impacts related to accommodating trucks in work zones [*192*]. The evaluation of the "Super 70" I-70 reconstruction project in Indianapolis conducted by Tarko et al. in 2011 [*56*] suggested that the rerouting of vehicles to alternative interstate routes contributed to improved safety performance.

2.2.3 Speed Control Strategies

Given the potential safety impacts of implementing work zones outlined in **Section 2.1**, including the increased risk for back-of-queue collisions, roadway agencies have employed a number of strategies intended to mitigate concerns related to vehicular speeds approaching or within highway work zones [*51*]. This ranges from conventional traffic control devices (such as portable or temporary rumble strips) to innovative ITS strategies (such as queue warning systems).

2.2.3.1 Portable or Temporary Rumble Strips

The use of portable or temporary rumble strips (**Figure 16**) for temporary traffic control is a common strategy employed by agencies that are intended to "alert drivers to unusual vehicular traffic conditions" according to the MUTCD [*20*]. These devices have been evaluated in a range of configurations and there is a considerable library of guidance towards their effective application [*13, 193-209*]. Prior research conducted by Ullman et al. [*12*] has included the development of CMFs specific to portable rumble strips, ranging from 0.40 to 0.89 depending on the scenario under evaluation.

	Preformed Thermoplastic	Pavement Marking Tape	Adhesive	Manually Adhesive	Portable Reusable
Adhesive	Polymer materials that are melted and fused to the pavement	Manufactured with a pre-applied adhesive	Manufactured with a removable adhesive backing	Require the application of a bonding/fastening agent such as adhesive cement, glues, or screws	Stay in place under their own weight; require no adhesives or fasteners
Assembly	Pre-cut strips manufactured in a two-part system: base layer & rumble bar	Pavement marking tapes come in manufactured rolls	Manufactured plastic strips come in 50 ft. rolls	Manufactured plastic rumble strips in pre-cut lengths	Modular plastic strips manufactured in 45 in. long sections of 35 lbs. each
Typical Size	3 ft. long Base– .125 in. thick; 4, 6, or 8 in. wide Bar – .25 in. thick; 2 in. wide	Can be layered and built up to the desired thickness	0.25 in. thick 4 in. wide Cut to desired length	4-6 ft. long 6 in. wide 0.25 in. thick	3 sections connect to form an 11 ft. rumble strip (105 lbs. total); 13 in. wide; .75 in. thick
Color	Black White Yellow Orange	White Black Yellow Others	Orange Black White	White (reflective available) Orange (reflective available) Black	Black

Figure 16. Examples of Portable or Temporary Rumble Strips [*195*]

2.2.3.2 Speed Feedback Displays

Speed feedback displays are a common strategy employed by roadway agencies to manage work zone speeds, typically consisting of a PCMS in conjunction with radar or other technology to monitor speeds (**Figure 17**) [*51*]. There is a vast amount of prior work that has evaluated the effectiveness of these systems and provided related guidance for their use [*210-*

225]. In general, this research has demonstrated that speed feedback displays are effective at reducing average speeds and increasing speed limit compliance [*51*]. While there is not work zone-specific CMF for speed feedback displays, prior research has suggested a value of 0.54 based on a meta-analysis of non-work zone evaluations [*13*].

Figure 17. Example of Speed Feedback Display Upstream of Work Zone [*226*]

2.2.3.3 Queue Warning Systems

Roadway agencies have experimented with a number of queue warning system treatments intended to address the potential crash risk associated with high-speed traffic approaching queues that have formed due to work zone capacity reductions [*51*, *227-231*]. These systems typically employ portable traffic data collection devices that relay information to PCMS to warn approaching drivers that a queue is present upstream (**Figure 18**). Agencies have also used portable or temporary rumble strips in conjunction with queue warning systems to enhance the warning message to drivers [*51*]. Prior research has included the development of CMFs specific to queue warning systems, ranging from 0.47 to 0.72 depending on the scenario under evaluation [*12, 227*].

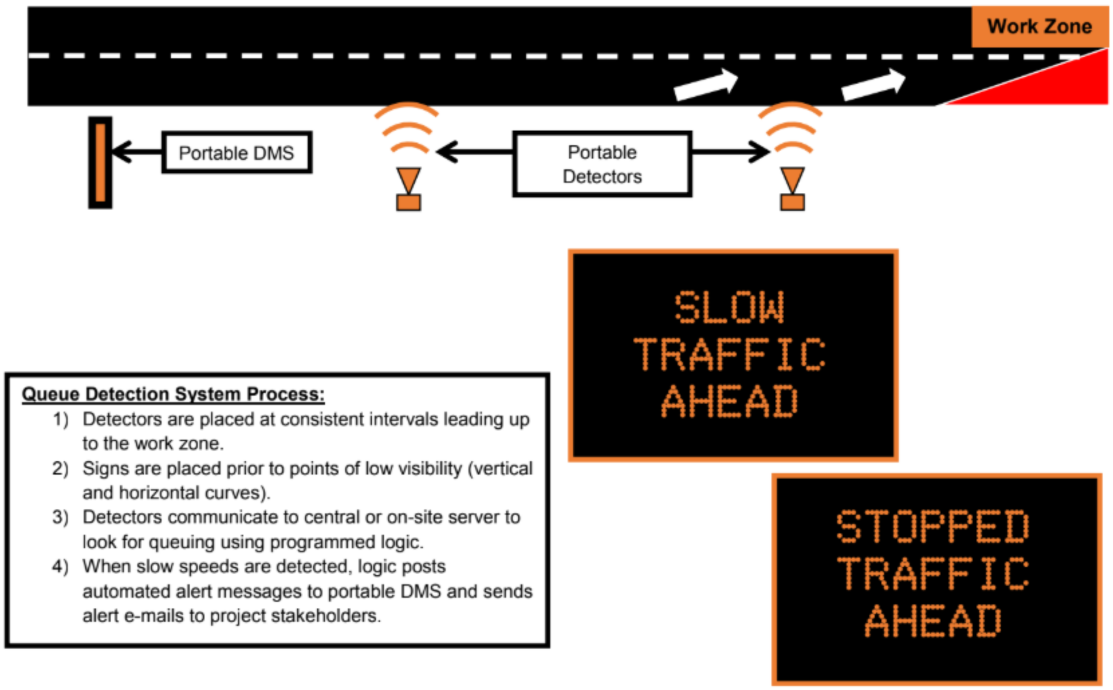


Figure 18. Iowa DOT's Queue Warning System [*232*]

2.2.3.4 Truck Warning Systems

Several state agencies have implemented truck warning systems, typically employing a PCMS to warn drivers of work zone hazards related to trucks [*51*], such as situations where trucks may be merging with traffic unexpectedly as well as overweight warning systems [*233*]. While there are no CMFs specific to this strategy, roadway agencies have included various truck warning systems within guidance materials for work zone TMP development [*174, 176, 232, 233*].

2.2.3.5 Variable Speed Limit Systems

While the use of variable speed limits may not be legal in all states, many roadway agencies have employed variable speed limit systems to mitigate both the safety and mobility impacts of highway work zones [*51*]. This typically involves the use of a changeable display mounted to a trailer to show speed limits for localized areas of a work zone depending on current conditions (such as congestion or weather conditions) [*234*]. While there is a wealth of prior research and guidance specific to variable speed limits in highway work zones [*234-245*], it should be noted that no work zone variable speed limit CMFs are currently available. However, prior work has suggested using a value of 0.92 developed using non-work zone data [*12*].

2.2.4 Pavement Marking Strategies

Roadway agencies have employed a number of common or experimental pavement marking strategies intended to mitigate work zone safety performance impacts. This includes the use of temporary raised pavement markings, improvements to retroreflectivity, wider lane markings, orange pavement markings, or painting the pavement surface black to eliminate existing markings [*51*]. It should be noted that both orange pavement markings and painting the pavement surface black may require a request to experiment with the FHWA [*161*].

Temporary raised pavement markings are intended to provide a "clear and defined" travel path for drivers through a work zone [*246*]. These devices represent a promising option for work zone scenarios where other temporary pavement markings are cost prohibitive [*246*].

Agencies have also evaluated a number of strategies to improve the retroreflectivity of pavement markings in work zones, including a recent special provision developed by MDOT [*247-251*]. While there are no CMFs specific to increasing retroreflectivity of pavement markings in work zones, prior research has suggested using a series of crash modification functions developed using non-work zone data [*12*]. Additionally, roadway agencies have experimented with wider lane lines (of greater than four inches) to potentially improve safety performance [*252-254*], including use within highway work zones [*255-257*].

Finally, roadway agencies have also used experimental approaches to reduce concerns related to "phantom" or "ghost" pavement markings within highway work zones [*51*]. This includes both orange pavement markings [*258, 259*] as well as painting the pavement surface black to eliminate the existing markings (**Figure 19**) [*260*].

Figure 19. Example of Painting Pavement Surface Black during Work Activity [*260*]

2.3 MDOT Work Zone Policies, Guidance, and Other Materials

MDOT's current published materials related to work zones (including policies, guidance, forms, and other related resources) were collected to support key project activities. These materials are summarized in **Table 4**. First, it was critical to have a comprehensive understanding of MDOT's current approach to temporary traffic control as a part of conducting the analyses presented in **Chapters 3 and 4**. Additionally, the recommendations provided within **Chapter 5** to optimize safety and mobility within Michigan work zones will ultimately be tied directly to MDOT's existing policies and guidance. These materials collected as a part of this process are summarized in **Table 4**, including a description of each resource.

Table 4. Summary of Michigan-Specific Resources Related to Work Zones

Resource	Description
MDOT's *Work Zone Safety and Mobility Manual [6]*	The processes, procedures, and guidelines to support the department's work zone policy [*5*] are detailed in MDOT's *Work Zone Safety and Mobility Manual* [*6*], which was most recently revised in February 2024. The manual also outlines the department's methods to evaluate safety and mobility within highway work zones. The "*decision tree*" justification process is discussed in more detail below.
Part 6 of the *Michigan Manual on Uniform Traffic Control Devices [261]*	Part 6 of Michigan's MUTCD [*261*] provides standards, guidance and support for the use of temporary traffic control for highway construction, utility work, maintenance operations, and traffic incidents. The Michigan version of the MUTCD was last updated in 2022.
MDOT's *Maintaining Traffic Typicals*	MDOT provides a list of current maintaining traffic typicals on its website [*262*] for stakeholders to access as a part of implementing temporary traffic control for construction areas. It should be noted MDOT maintains distinct typicals for ramp design and layout, as opposed to just referring to the MUTCD.
MDOT's *Work Zone Review Report [263]*	The department's *Work Zone Review Report* [*263*] is used by staff to complete work zone reviews consistent with the *Work Zone Safety and Mobility Manual* [*6*].
MDOT's *Special Provisions*	The department maintains a list of special provisions [*264*] that are previously approved for inclusion in proposal documentation. Division 8 – 812 covers temporary traffic control for construction zone operations.
MDOT's *2020 Standard Specifications for Construction* [*265*]	MDOT's *2020 Standard Specifications for Construction* [*265*] represents the basic requirements for the materials, equipment and methods used in construction contracts that are administered by the department.

Resource	Description
MDOT's *Maintenance Work Zone Traffic Control Guidelines [266]*	MDOT's guidance document, last updated in 2007, focused on the placement of temporary traffic control for maintenance work zones in Michigan.
MDOT's *Michigan Traffic Regulator's Instruction Manual* [*267*]	Handbook maintained by MDOT intended for traffic regulators within construction, maintenance, and utility work zones in Michigan. It should be noted that the handbook was last updated in 2010.
UD-10 Traffic Crash Report 2021 Instruction Manual [268]	The instruction manual provides guidance to Michigan's UD-10 traffic crash report. Specific to work zones, the manual provides guidance for the four work zone-related fields added to the UD-10 in 2016.
MDOT's Work Zone Safety *Fast Facts* Page [*269*]	MDOT maintains a webpage [*269*] that provides recent work zone traffic crash statistics and information. Additionally, the department maintains a "Work Zones 101" flyer for public information [*270*].

A core component of MDOT's work zone process is the development of a transportation management plan (TMP), which is a dynamic document that includes the detailed information for managing impacts to safety and mobility during the life of a specific project [*6*]. While TMPs are required for all construction projects, the data and analyses that are required depend on the level of significance of the project [*6*]. This includes projects that are expected to result in delays greater than ten minutes when compared to normal conditions, design-build projects, as well as projects that incorporate alternative technical concepts to maintain traffic [*6*]. While the level of detail is determined by the MDOT project manager, TMPs for significant projects must include a temporary traffic control plan (TTCP), a traffic operations plan (TOP), a public information plan (PIP), and a performance assessment plan (PAP) [*6*].

A recent addition to MDOT's *Work Zone Safety and Mobility Manual* [*6*] is the "*decision tree"* justification process, outlined in Section 1.02.08 of the manual. The decision tree is a flowchart (**Figure 20**) intended to identify appropriate strategies to mitigate work zone safety and mobility impacts on road users as well as protect road workers. The use of this decision tree is required for projects on roadways with posted speed limits of 70 mph or greater and optional for all other projects. This process is consistent with other agencies throughout the United States, where mitigation strategies commonly employed to maintain mobility and maximize safety in work zones generally includes a combination of the following considerations [*11*]:

- Construction approach (such as the staging or sequencing of activities, implementing alternative work schedules, or considering lane or ramp closure alternatives)
- Design elements (such as lane width, crossovers, or the construction of temporary facilities)
- Traffic control elements (such as speed limit reductions, truck restrictions, or signal timing)
- Public information (including public outreach or the use of dynamic message signs)
- Incident management and enforcement (such as coordinating with traffic operations centers, emergency service patrols, or work zone-specific enforcement activity)
- Travel demand management (such as providing incentives to use other routes or modes)

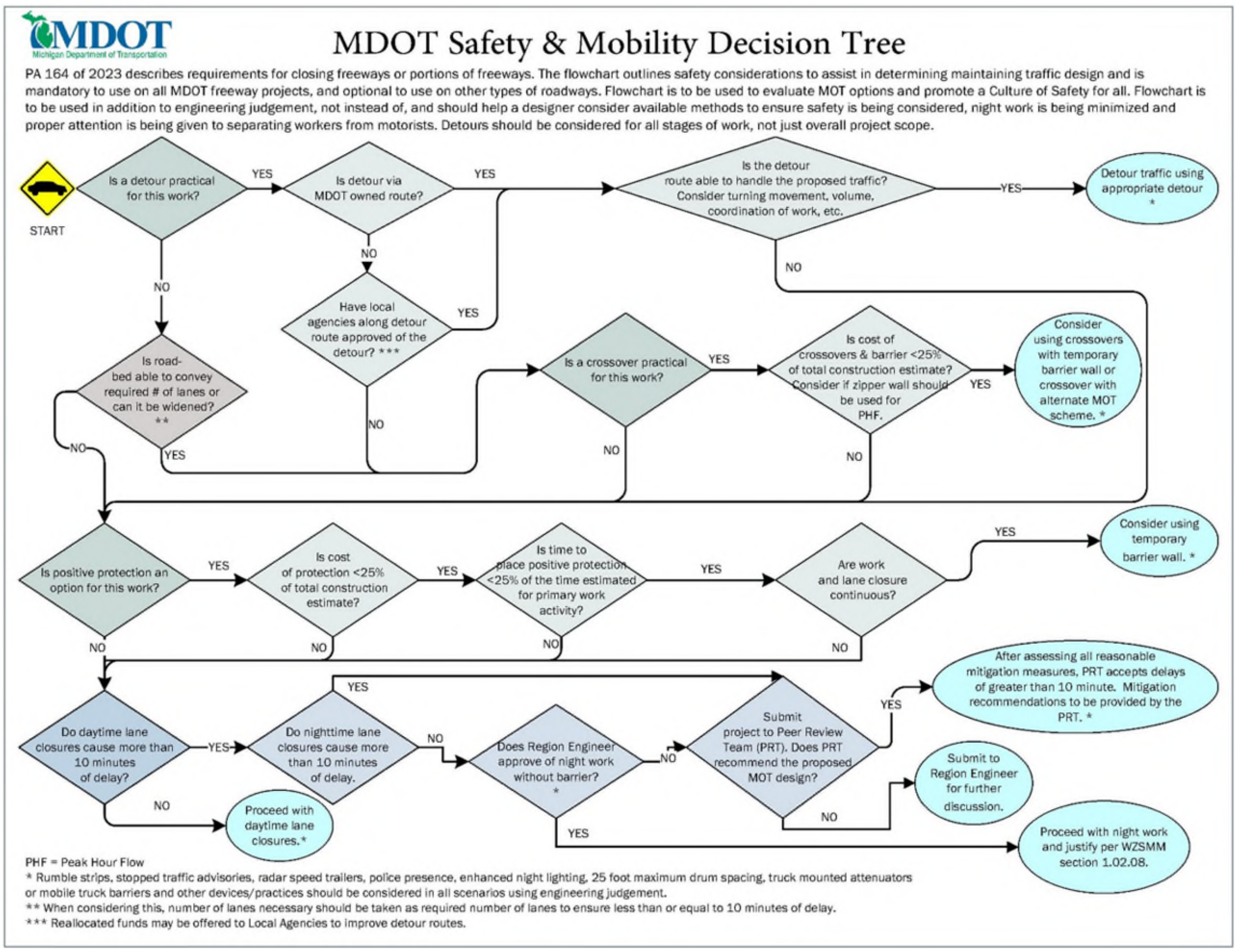


Figure 20. Existing MDOT Safety & Mobility Decision Tree (as of February 2024) [*6*]

3.0 ANALYSIS OF STATEWIDE WORK ZONE CRASH DATA

A detailed analysis of historical statewide traffic crash data specific to highway work zones was conducted in order to quantify recent trends with respect to work zone safety both within Michigan and around the country. The findings summarized below can be used as a roadmap to target statewide work zone crash patterns or circumstances in order to accelerate progress towards MDOT's long-term zero death vision [*271*]. Towards this end, the specific objectives of the statewide analysis included:

- The collection of historical work zone traffic crash data within Michigan and the combination of these data with other roadway characteristics in order to both complete a statewide analysis as well as provide guidance for the analysis of 25 distinct work zones presented in **Chapter 4**.
- The review of each diagram and narrative included within the Michigan UD-10 traffic crash report form for all work zone-coded crashes resulting in a fatality or serious injury as well as all work zone crashes involving non-motorized road users.
- The identification of recent trends in crash patterns or circumstances within Michigan and compare these trends with the national experience in order to find opportunities to improve work zone safety performance from a statewide perspective.

3.1 Data Collection

Initially, statewide traffic crash records coded as having occurred within a construction or maintenance work zone by the responding officer were collected from the annual databases maintained by the Michigan State Police for the six-year period between 2017 and 2022 (**Figure 21**). While the Michigan State Police made changes to the Michigan UD-10 crash report form to include new data elements specific to traffic crashes occurring in work zones in 2016, these fields were not consistently used by responding officers until 2017 and therefore crash data from 2016 were not included in the statewide analysis. Additionally, 18 traffic crash records with incomplete location information were removed from the statewide analysis. A total of 30,889 construction and maintenance work zone-coded crash records were identified as a part of this process, summarized by the worst injury in the crash in **Table 5**.

It is critical to recognize that the data and analysis presented below are based on the coding on the UD-10 crash report form as recorded by the responding officer. As will be demonstrated within **Chapter 4** based on the analysis of individual work zones, this does not represent all crashes that occurred within highway work zones during this period. This is due to the fact that there are a number of crash records that erroneously are not coded as having occurred within a work zone despite temporary traffic control being in place. Further, **Chapter 4** will also demonstrate that there is considerable error within the newly added work zone fields (in particular the construction activity and location fields). Therefore, the findings presented within **Sections 3.2 to 3.5** should be interpreted as an estimate of general trends in Michigan, with the recognition that the total number of work zone collisions is likely underreported.

Figure 21. Michigan Work Zone Traffic Crashes (2017-2022)

Table 5. Work Zone Crash Frequency by Worst Injury in Crash (2017-2022)

Worst Injury in Crash	2017	2018	2019	2020	2021	2022	Total	Share
Fatal (K)	21	15	14	11	18	22	**101**	**0.3%**
Serious Injury (A)	58	44	74	56	63	92	**387**	**1.3%**
Minor Injury (B)	166	214	282	202	278	365	**1,507**	**4.9%**
Possible Injury (C)	528	632	686	484	696	925	**3,951**	**12.8%**
Property Damage Only	3,292	3,738	4,538	3,084	4,514	5,787	**24,953**	**80.8%**
All Severities	**4,065**	**4,643**	**5,594**	**3,837**	**5,569**	**7,191**	**30,899**	**100.0%**

Michigan has experienced an annual average of approximately 5,150 construction or maintenance work zone-coded traffic crashes per year during the six-year study period, including approximately 17 collisions resulting in a fatality and 65 collisions resulting in a serious injury. Work zone-coded collisions in Michigan represented approximately 1.5 percent of all traffic crashes and 1.7 percent of fatal crashes during the study period.

3.1.1 Review of Michigan UD-10 Crash Report Forms

While the new work zone-related fields included within the Michigan UD-10 crash report form implemented in 2016 provide an opportunity to conduct more detailed analyses of work zone safety performance in Michigan, additional information about each crash can also be obtained by reviewing the narrative and diagram included with the report (**Figure 22**). UD-10 crash report forms were obtained for all severe work zone collisions resulting in a fatality or serious injury, as well as all work zone collisions involving a pedestrian or bicyclist. As a part of this review, key characteristics of each record were also evaluated (such as crash type or the precise location) to ensure that the data was reflective of actual conditions. A total of 670 crash reports were reviewed as a part of this process, including 97 collisions where key characteristics associated with the record were modified from the original data (or approximately 15 percent).

The specific circumstances of each crash, with a focus on the involvement of work zone traffic control, workers, work vehicles, or equipment were also assessed. This allowed for the identification of common circumstances related to crashes with severe (fatal and serious) injury outcomes as well as crashes that involved non-motorized road users.

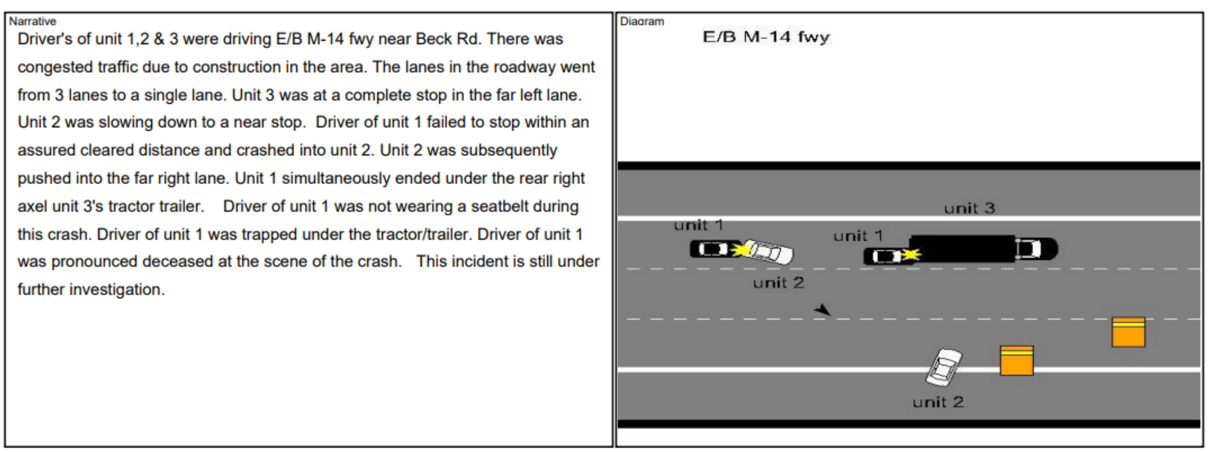


Figure 22. Example of Michigan UD-10 Crash Report Form Narrative and Diagram

3.1.2 Collection of National Work Zone Data

National work zone crash data were also collected in order to compare the national experience with trends observed within Michigan. This was completed by using the National Highway Traffic Safety Administration's (NHTSA) *Fatality and Injury Reporting System Tool* (FIRST) [*272*], which includes data from both the *Fatality Analysis Reporting System* (FARS) [*273*] and the *Crash Report Sampling System* (CRSS) [*274*]. FARS "contains data on a census of fatal traffic crashes within the 50 States, the District of Columbia, and Puerto Rico" [*273*]. FARS data is developed from existing state resources and includes records for crashes involving a vehicle traveling along a public traffic way that involved a fatality within 30 days of the collision [*273*]. CRSS represents "a sample of police-reported crashes involving all types of motor vehicles, pedestrians, and cyclists, ranging from property-damage-only crashes to those that result in fatalities" [*274*]. This sample is ultimately used to develop an estimate of traffic crashes occurring across the United States [*274*].

National work zone traffic crash data were obtained by querying FIRST for crash counts occurring within "construction", "maintenance", or "unknown" work zones (excluding "utility" work zone collisions). Within FIRST, fatal crash data are provided by FARS and estimates of injury only and property damage only (PDO) data are provided by CRSS. Given that data for 2022 was not yet available in FIRST, five years of national work zone crash data were obtained (2017-2021) to be as consistent as possible with the sample of Michigan work zone crash data. These data are summarized by year in **Table 6**.

Table 6. National Work Zone Crash Data from FARS and CRSS by Severity (2017-2021)

Severity	Source	2017	2018	2019	2020	2021	Total
Fatal Crashes	FARS	709	671	751	772	856	**3,759**
Estimated Injury Only	CRSS	25,486	29,987	26,428	30,566	28,869	**141,336**
Estimated PDO Only	CRSS	66,885	91,079	86,677	68,959	75,214	**388,814**

Comparisons in work zone crash patterns by type, severity, or other categories observed between the national and Michigan data are provided in **Sections 3.2 to 3.4**. This allows for the identification of trends where Michigan has varied from the national experience and represents potential opportunities to target to accelerate progress towards the state's safety goals.

3.2 Statewide Work Zone Safety Performance

While the annual frequency of all traffic crashes occurring across Michigan is heavily correlated with statewide vehicle miles traveled (VMT), annual work zone-coded crash frequencies in general are less sensitive to these statewide travel trends (**Figure 23**). A major exception to this was the 2020 COVID-19 pandemic that resulted in dramatic reductions in statewide VMT, total crash frequency, and work zone-coded crash frequency.

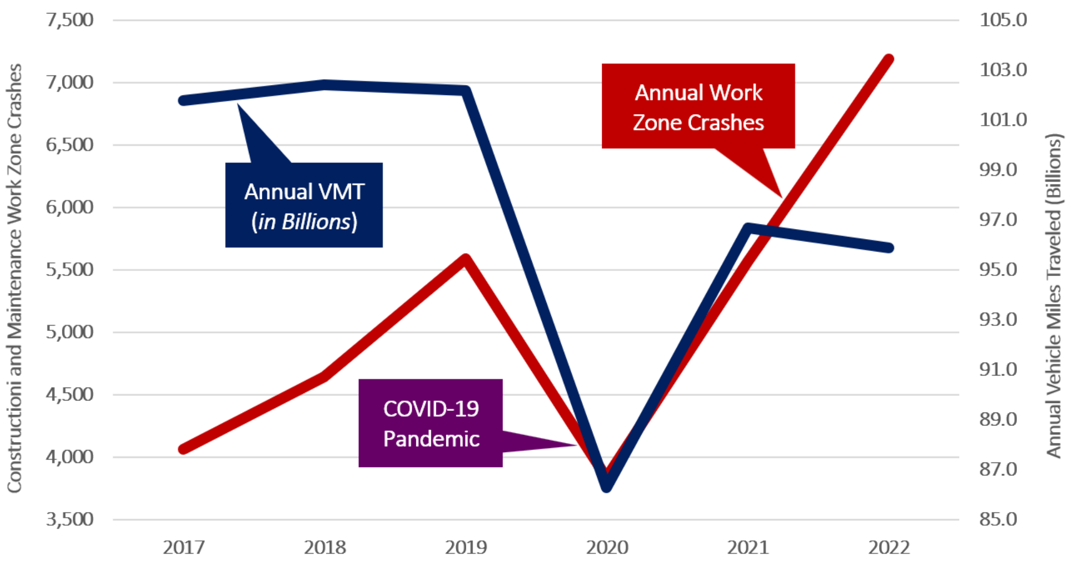


Figure 23. Michigan Work Zone Traffic Crashes vs. Statewide VMT (2017-2022)

Instead, the annual frequency of statewide work zone-coded crashes is largely driven by the amount of road work conducted in any given year. **Figure 24** compares the annual statewide work zone-coded crash frequency with annual MDOT gross appropriations [*275*].

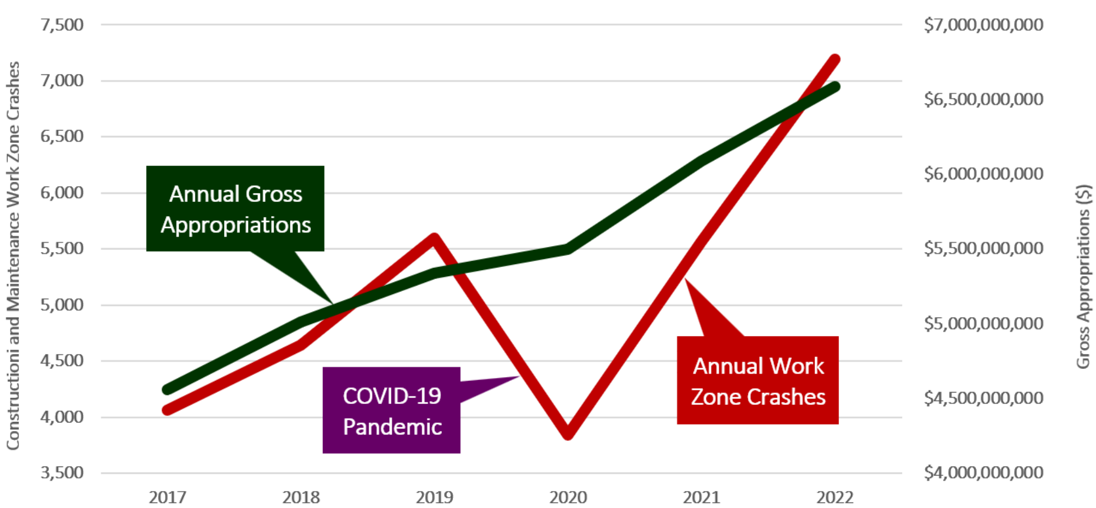


Figure 24. Work Zone Traffic Crashes vs. MDOT Gross Appropriations (2017-2022)

These work zone-coded crashes are principally comprised of rear end collisions (45.6 percent), sideswipe same-direction collisions (20.4 percent), and single vehicle collisions (17.5 percent), shown in **Table 7**. Head on (0.5 percent), head on left-turn (1.1 percent), and sideswipe opposite-direction (1.0 percent) work zone collisions are relatively rare.

Table 7. Work Zone Crash Frequency by Crash Type (2017-2022)

Crash Type	2017	2018	2019	2020	2021	2022	Total	Share
Single Vehicle	674	733	896	783	1,048	1,260	**5,394**	**17.5%**
Head On	15	27	25	26	33	37	**163**	**0.5%**
Head On Left-Turn	59	48	69	60	38	55	**329**	**1.1%**
Angle	371	491	502	357	411	510	**2,642**	**8.6%**
Rear End	1,927	2,110	2,664	1,576	2,545	3,283	**14,105**	**45.6%**
Sideswipe Same	756	908	1,079	753	1,137	1,657	**6,290**	**20.4%**
Sideswipe Opposite	44	58	59	45	58	54	**318**	**1.0%**
Other/Unknown	219	268	300	237	299	335	**1,658**	**5.4%**
All Crash Types	**4,065**	**4,643**	**5,594**	**3,837**	**5,569**	**7,191**	**30,899**	**100.0%**

When compared to the national experience, Michigan tends to observe a larger proportion of rear end work zone-coded collisions and a smaller proportion of single vehicle collisions (**Table 8**). This is particularly true for fatal crashes where 41.6 percent of work zone-coded traffic crashes in Michigan resulting in a fatality were rear end collisions, compared to 22.8 percent across the United States.

Table 8. Michigan vs. National Work Zone Crashes by Crash Type and Severity

Severity	Location	Crash Type					
		Single Vehicle	Head-On	Angle	Rear-End	Sideswipe	Other
Fatal	**Michigan**	31.7%	1.0%	3.0%	41.6%	6.9%	15.8%
	National	54.4%	7.4%	10.7%	22.8%	3.6%	1.1%
Injury	**Michigan**	17.4%	3.5%	12.4%	54.1%	9.0%	3.6%
	National	25.6%	2.0%	16.7%	42.8%	11.6%	1.3%
PDO	**Michigan**	17.4%	1.2%	7.7%	43.7%	24.3%	5.7%
	National	22.4%	0.7%	12.2%	39.4%	23.7%	1.7%

With respect to the new work zone-specific fields added to the Michigan UD-10 crash report form in 2016, **Tables 9-11** summarize work zone-coded crash frequency by worker presence, work activity, and crash location.

Table 9. Work Zone Crash Frequency by Worker Presence (2017-2022)

Worker Presence	2017	2018	2019	2020	2021	2022	Total	Share
Present	1,565	1,590	1,807	1,258	1,722	2,052	**9,994**	**32.3%**
Not Present	2,500	3,053	3,787	2,579	3,847	5,139	**20,905**	**67.7%**
Unknown	52	5	0	0	0	3	**60**	**0.2%**
All Conditions	**4,065**	**4,643**	**5,594**	**3,837**	**5,569**	**7,191**	**30,899**	**100.0%**

Table 10. Work Zone Crash Frequency by Work Activity (2017-2022)

Work Activity	2017	2018	2019	2020	2021	2022	Total	Share
Lane Closure	2,503	2,935	3,753	2,461	3,758	4,686	**20,096**	**65.0%**
Lane Shift or Crossover	515	703	728	568	834	1,120	**4,468**	**14.5%**
Work on Shoulder or Median	521	415	492	312	452	652	**2,844**	**9.2%**
Intermittent or Moving Work	194	208	240	178	207	231	**1,258**	**4.1%**
Other/Unknown	332	382	381	318	318	502	**2,233**	**7.2%**
All Activity Types	**4,065**	**4,643**	**5,594**	**3,837**	**5,569**	**7,191**	**30,899**	**100.0%**

Table 11. Work Zone Crash Frequency by Crash Location (2017-2022)

Crash Location	2017	2018	2019	2020	2021	2022	Total	Share
Before Warning Sign	364	357	440	340	438	535	**2,474**	**8.0%**
Between Warning Signs	3,232	3,848	4,784	3,173	4,808	6,289	**26,134**	**84.6%**
No Warning Signs	417	431	370	324	323	365	**2,230**	**7.2%**
Other/Unknown	52	7	0	0	0	2	**61**	**0.2%**
All Locations	**4,065**	**4,643**	**5,594**	**3,837**	**5,569**	**7,191**	**30,899**	**100.0%**

Approximately one third of work zone-coded collisions in Michigan occur when workers are present, highlighting the potential risks for road workers who are performing tasks adjacent to the traveled way. Lane closures are by far the most common work activity associated with work zone-coded traffic crashes (65.0 percent), followed by lane shifts or crossovers (14.5 percent) and work on the shoulder or in the median (9.2 percent). Intermittent or moving work zones were associated with only 4.1 percent of all work zone-coded collisions. The overwhelming majority (84.6 percent) of work zone-coded collisions occur between the first and last warning signs, including approximately three-quarters of all fatal work zone collisions that occurred in Michigan during the six-year study period.

Beyond the new work zone-specific fields included on the Michigan UD-10 crash report form, several categories of work zone-coded collisions were identified by using other fields available within annual crash databases (**Table 12**). These categories were also compared to the national experience in **Table 13**.

Table 12. Work Zone Crash Frequency by Category (2017-2022)

Category	2017	2018	2019	2020	2021	2022	Total	Share
Truck-Involved	398	547	719	494	806	1,020	**3,984**	**12.9%**
Motorcycle-Involved	46	41	58	42	55	74	**316**	**1.0%**
Pedestrian-Involved	23	38	42	33	25	33	**194**	**0.6%**
Bicycle-Involved	11	6	11	7	10	8	**53**	**0.2%**
Involved Young Driver (15-20)	692	774	840	598	869	1,006	**4,779**	**15.5%**
Involved Older Driver (65+)	843	914	1,119	699	1,083	1,354	**6,012**	**19.5%**
Alcohol-Involved	120	129	154	145	182	209	**939**	**3.0%**
Drugs-Involved	36	32	40	48	58	51	**265**	**0.9%**

Table 13. Michigan vs. National Work Zone Crashes by Category and Severity

Severity	Location	Category					
		Truck	Motorcycle	Pedestrian	Bicycle	Young Driver	Older Driver
Fatal	**Michigan**	31.7%	15.8%	21.8%	1.0%	11.9%	20.8%
	National	30.9%	13.5%	18.2%	1.3%	9.7%	20.6%
Injury	**Michigan**	11.0%	3.6%	2.3%	0.7%	16.7%	20.7%
	National	13.4%	3.9%	2.8%	0.8%	17.1%	17.9%
PDO	**Michigan**	13.3%	0.4%	0.1%	0.0%	15.2%	19.2%
	National	20.6%	0.3%	0.2%	0.1%	17.8%	19.2%

While traffic crashes involving large trucks represented 12.9 percent of all work zone-coded collisions, such truck-involved crashes represented nearly one-third of all fatal work zone collisions. A similar trend can be observed for motorcycle-involved collisions, where such crashes represented only 1.0 percent of all work zone crashes but 15.8 percent of fatal work zone crashes. Pedestrian-involved collisions represented less than one percent of all work zone collisions but approximately one-fifth of all fatal work zone collisions. It is worth noting that the general trends by category are in general agreement with the national experience as shown in **Table 13.**

The distribution of Michigan work zone-coded crashes by severity and light condition are shown in **Table 14** and the distribution by crash type and light condition are shown in **Table 15**.

Table 14. Distribution of Crashes by Worst Severity and Light Condition (2017-2022)

Light Condition	Fatal (K)	Serious Injury (A)	Minor Injury (B)	Possible Injury (C)	PDO	All Severities
Daylight	57.4%	63.8%	73.6%	77.7%	78.1%	**77.6%**
Dark - Lighted	18.8%	17.8%	12.0%	11.6%	9.8%	**10.2%**
Dark - Unlighted	21.8%	15.2%	10.4%	7.2%	8.0%	**8.2%**
Other	2.0%	3.1%	4.0%	3.6%	4.1%	**4.0%**
All Conditions	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Table 15. Distribution of Crashes by Type and Light Condition (2017-2022)

Crash Type	Daylight	Dark - Lighted	Dark - Unlighted	Other
Single Vehicle	11.9%	29.4%	50.3%	28.2%
Head On	0.3%	1.2%	1.3%	0.8%
Head On Left-Turn	1.1%	1.7%	0.2%	1.3%
Angle	9.1%	9.6%	2.9%	6.2%
Rear End	49.5%	36.1%	24.7%	38.8%
Sideswipe Same	21.5%	16.4%	15.7%	18.2%
Sideswipe Opposite	1.0%	0.9%	0.9%	1.4%
Other or Unknown	5.6%	4.6%	4.1%	5.1%
All Crash Types	**100.0%**	**100.0%**	**100.0%**	**100.0%**

While more than three-quarters of all work zone-coded crashes occur during daylight conditions, it can be observed from **Table 14** that fatal and serious injury collisions become more common in dark conditions with or without lighting present. Approximately 35 percent of fatal and serious injury work zone crashes occur in dark conditions with or without lighting present compared to only approximately 18 percent of property damage only work zone crashes. A primary difference between daylight and dark condition work zone crashes is the share of single vehicle and rear end collisions, where rear end collisions are more common during the day (when work zone congestion is most prevalent) and single vehicle collisions are more common at night.

3.2.1 Work Zone Crashes by Roadway Type

In order to provide a more detailed evaluation of statewide work zone safety performance, the historical work zone traffic crash data outlined above was associated with Michigan roadway inventory data for both trunkline and non-trunkline facilities [*276*]. This allowed for disaggregating the data by roadway type, as shown in **Table 16**. Work zone crashes were most common along mainline freeway segments (39.7 percent) and non-freeway arterials (49.6 percent). **Section 3.3** provides an overview of freeway work zone safety performance and **Section 3.4** provides an overview of non-freeway work zone safety performance.

Table 16. Work Zone Crashes by Roadway Type and Severity (2017-2022)

Roadway Type	Fatal (K)	Serious Injury (A)	Minor Injury (B)	Possible Injury (C)	PDO	All Severities	Share
Freeways	60	152	580	1,594	9,877	**12,263**	**39.7%**
Freeway Ramps	3	12	40	112	771	**938**	**3.0%**
Arterials	29	184	740	2,027	12,339	**15,319**	**49.6%**
Collectors	8	22	104	139	997	**1,270**	**4.1%**
Local Roads	1	17	43	79	969	**1,109**	**3.6%**
All Road Types	**101**	**387**	**1,507**	**3,951**	**24,953**	**30,899**	**100.0%**

3.2.2 Traffic Crashes involving Workers on Foot

In addition to the safety effects of construction work on Michigan's road users, it was also essential to identify potential trends specific to traffic crashes involving road workers in order to achieve the state's safety goals. A total of 116 work zone-coded traffic crash records were identified during the six-year study period where the circumstances outlined in the crash report form diagram and narrative indicated that a worker on foot was involved (shown in **Figure 25**). A summary of these 116 collisions by the worst injury and roadway type is presented in **Table 17**.

As discussed within **Section 3.1**, there were likely additional collisions beyond the 116 identified by the research team that involved workers on foot that were not captured as a part of this process. These additional crashes were not captured due to limitations associated with the work zone crash report fields outlined in **Chapter 4**. Therefore, the findings presented within **Figure 25** and **Table 17** should be interpreted with caution and may not represent all collisions involving workers on foot during this period.

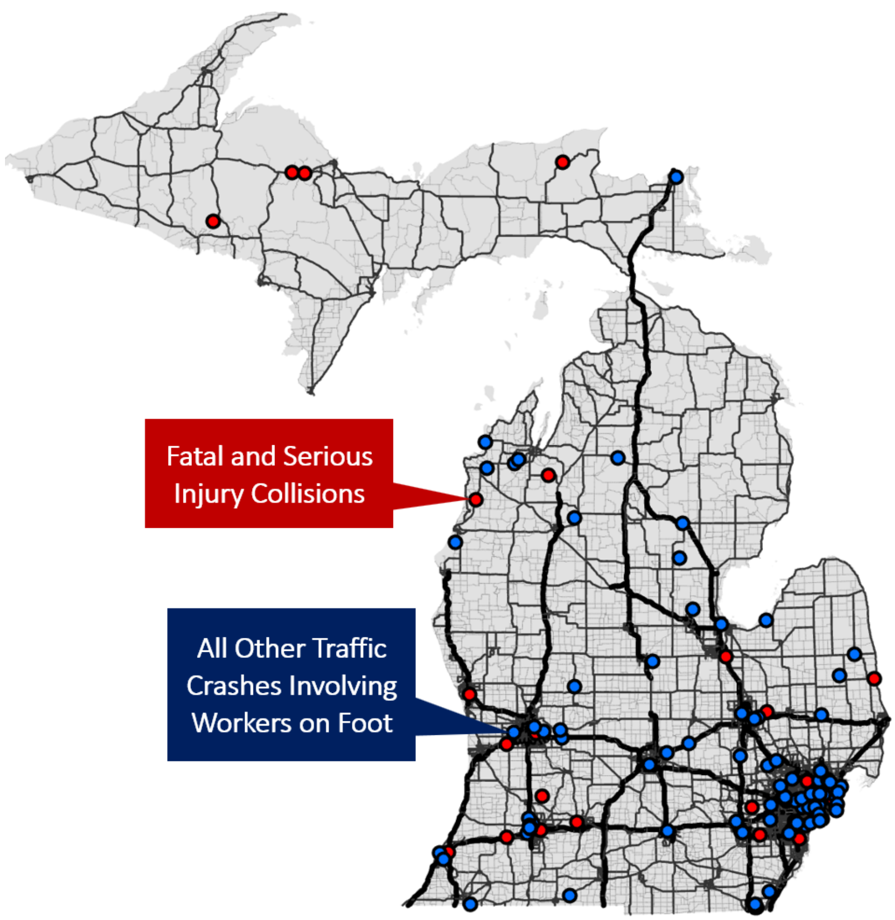


Figure 25. Work Zone-Coded Traffic Crashes involving Workers on Foot (2017-2022)

Table 17. Crashes involving Workers on Foot by Roadway Type and Worst Injury (2017-2022)

Circumstance		Fatal (K)	Serious Injury (A)	Minor Injury (B)	Possible Injury (C)	PDO	Total
Freeways	Worker Struck by Vehicle Entering Work Area	4	2	2	1	1	**10**
	Worker Struck by Vehicle while Placing Traffic Control Devices	0	0	1	1	0	**2**
	Worker Struck by Loose Object from Passing Vehicle	1	0	0	0	0	**1**
	Worker Struck by Work Vehicle	0	1	0	0	0	**1**
Arterials	Flagger or Other Worker Struck by Vehicle that Disregarded Flagger Control	0	0	5	9	7	**21**
	Worker Struck by Vehicle Entering Work Area for Other Reason	2	6	6	13	4	**31**
	Worker Struck by Work Vehicle	0	3	0	0	1	**4**
	Worker Struck by Vehicle while Placing Traffic Control Devices	0	0	0	1	0	**1**
	Other Circumstance Related to Work Zone Presence	0	0	0	1	1	**2**
Collectors	Flagger or Other Worker Struck by Vehicle that Disregarded Flagger Control	1	2	4	4	6	**17**
	Worker Struck by Vehicle Entering Work Area for Other Reason	0	0	1	4	0	**5**
	Worker Struck by Vehicle while Placing Traffic Control Devices	0	0	0	0	1	**1**
	Other Circumstance Related to Work Zone Presence	0	0	0	1	0	**1**
Local Roadways	Flagger or Other Worker Struck by Vehicle that Disregarded Flagger Control	0	0	0	1	5	**6**
	Worker Struck by Vehicle Entering Work Area for Other Reason	0	4	1	4	2	**11**
	Worker Struck by Work Vehicle	0	1	0	1	0	**2**
	All Work Zone-Coded Crashes Involving Workers on Foot	**8**	**19**	**20**	**41**	**28**	**116**

While the greatest concentration of crashes involving road workers on foot is located within the metropolitan Detroit area, **Figure 25** also demonstrates that severe collisions resulting in fatalities or serious injuries regularly occur across the state. In fact, four such severe collisions involving workers on foot occurred along the non-freeway network in the Upper Peninsula during the six-year study period. **Table 17** demonstrates that fatalities and serious injuries most often occur due to errant vehicles entering the work area. Additionally, such severe collisions involving workers on foot are more evenly distributed across all four roadway types than severe work zone traffic crashes as a whole (as shown in **Table 16**).

3.3 Statewide Freeway Work Zone Safety Performance

A total of 13,201 work zone-coded crashes occurred along Michigan's freeway network during the six-year study period, including 63 collisions resulting in a fatality (**Table 18**). As shown in **Figure 26**, freeway work zone crashes intuitively are concentrated along areas where substantial reconstruction projects occurred during the study period (such as the I-75 modernization project in southeast Michigan).

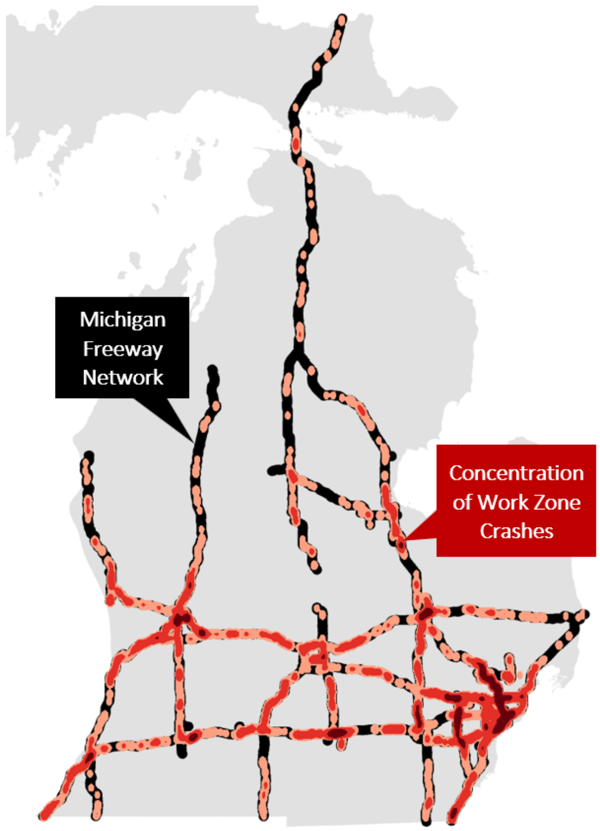


Figure 26. Concentrations of Work Zone Crashes along Michigan's Freeway Network

Table 18. Summary of Michigan Freeway Work Zone Crash Data (2017-2022)

Crash Type	Fatal (K)	Serious Injury (A)	Minor Injury (B)	Possible Injury (C)	PDO	All Severities
Single Vehicle	15	45	183	284	2,393	**2,920**
Head On	0	3	5	8	7	**23**
Head On Left-Turn	0	0	0	0	3	**3**
Angle	0	3	9	7	33	**52**
Rear End	31	89	325	1,148	5,106	**6,699**
Sideswipe Same	6	18	66	201	2,717	**3,008**
Sideswipe Opposite	0	0	0	3	18	**21**
Other/Unknown	11	6	32	55	371	**475**
All Crash Types	**63**	**164**	**620**	**1,706**	**10,648**	**13,201**

Nearly half of fatal freeway work zone crashes in Michigan are rear end collisions (**Table 19),** compared to approximately one-third nationwide. While Michigan tends to observe a smaller share of alcohol-involved fatal work zone crashes (20.6 percent) than the country as a whole (32.8 percent), the experience is similar with respect to the other categories (**Table 20**).

Table 19. Michigan vs. National Fatal Freeway Work Zone Crashes by Crash Type

Location	Single Vehicle	Head-On	Angle	Rear-End	Sideswipe	Other
Michigan	25.8%	0.0%	0.0%	48.5%	9.1%	16.7%
National	53.5%	2.7%	3.9%	33.8%	4.8%	1.4%

Table 20. Michigan vs. National Fatal Freeway Work Zone Crashes by Category

Location	Truck	Motorcycle	Pedestrian	Bicyclist	Young Driver	Older Driver	Alcohol
Michigan	42.9%	19.0%	12.7%	0.0%	14.3%	15.9%	20.6%
National	39.6%	12.5%	16.3%	0.2%	8.4%	17.9%	32.8%

A total of 227 fatal and serious injury work zone crashes occurred along Michigan's freeway network during the six-year study period, shown in **Table 21** by the circumstance obtained from the UD-10 crash report form review. While any collision that occurs within a work zone could be related to the presence of work zone traffic control, workers, work vehicles, or equipment, **Table 21** identifies the subset of fatal and serious injury work zone crashes that were directly related to the presence of a work zone.

Table 21. Fatal and Serious Injury Freeway Work Zone Crashes by Circumstance (2017-2022)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Rear End Collision Related to Work Zone Congestion	**90**	**39.6%**
	Workers and/or Work Vehicles Struck by Vehicle Entering Work Area	**11**	**4.8%**
	Single Vehicle Collision Involving Work Zone Traffic Control	**11**	**4.8%**
	Sideswipe Same Collision Directly Related to Lane Closures	**7**	**3.1%**
	Other Circumstances Related to Work Zone Presence	**10**	**4.4%**
Other Motor Vehicle Crashes in Work Zone	Collision Due to Lane Departure or Loss of Control	**37**	**16.3%**
	Rear End Collision Not Directly Related to Work Zone Presence	**20**	**8.8%**
	Pedestrian Struck by Vehicle while Attempting to Cross Freeway	**5**	**2.2%**
	Driver Fell Asleep or Had Medical Emergency	**11**	**4.8%**
	Sideswipe Same Collision Not Directly Related to Work Zone Presence	**10**	**4.4%**
	Other Circumstances Not Directly Related to Work Zone Presence	**15**	**6.6%**
All Fatal (K) and Serious (A) Injury Freeway Work Zone Crashes		**227**	**100.0%**

More than half of severe crashes (56.8 percent) occurring within a freeway work zone were directly related to the presence of work zone traffic control, workers, work vehicles, or equipment. Rear end collisions related to work zone congestion (39.6 percent) represent the most common circumstance during the six-year study period. Other circumstances directly related to work zone presence identified in **Table 21** include vehicles entering the work area and striking workers and/or equipment (4.8 percent), single vehicle collisions related to work zone traffic control (4.8 percent), and sideswipe same-direction collisions (3.1 percent).

Given the overrepresentation of rear end crashes in Michigan compared to the national experience as shown in **Table 19**, the identification of safety treatments intended to reduce rear end collisions related to work zone congestion represents the greatest opportunity to accelerate progress towards the state's safety goals. **Figure 27** provides further detail regarding these 90 collisions by category. **Table 22** provides a summary of these 90 collisions by work activity and work location.

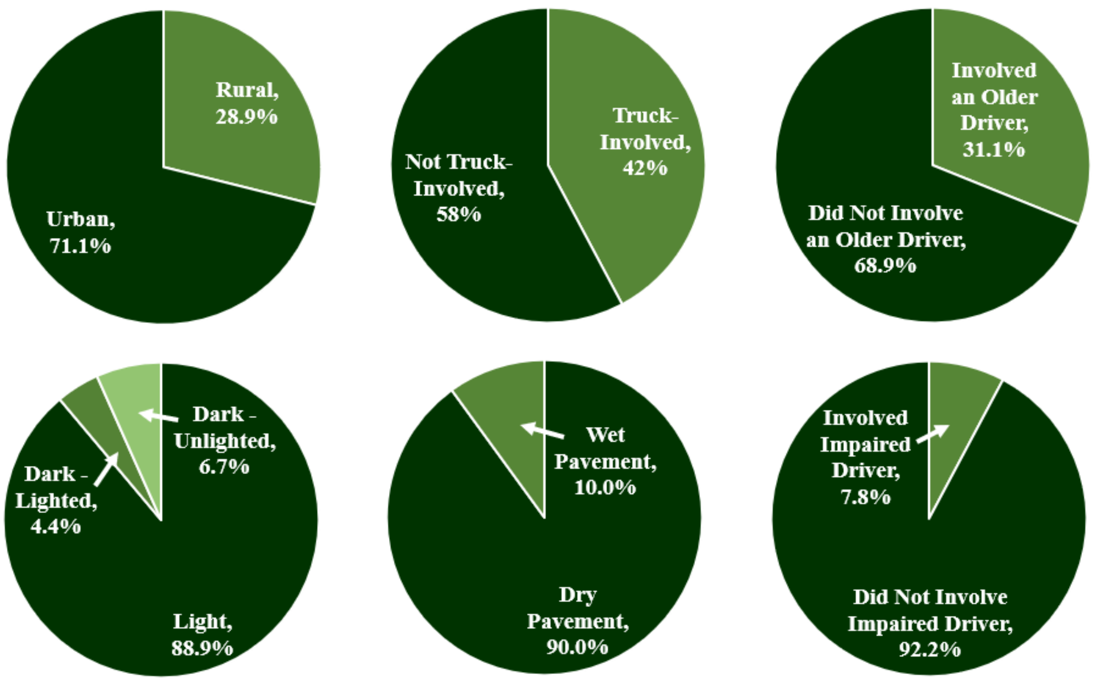


Figure 27. Freeway Fatal and Serious Injury Rear End Collisions involving Work Zone Congestion by Category (N = 90)

Table 22. Freeway Fatal and Serious Injury Rear End Collisions involving Work Zone Congestion by Work Activity and Work Location (2017-2022)

Work Activity	Before Warning Sign	Between Warning Signs	No Warning Signs	Other or Unknown
Lane Closure	11	54	1	1
Lane Shift or Crossover	1	9	0	0
Work on Shoulder or Median	0	5	0	0
Intermittent or Moving Work	1	0	0	0
Other/Unknown	3	3	0	1

While the majority of these collisions occur in urban environments (71.1 percent), it should be noted that the 28.9 percent occurring in rural environments represents a higher share than rural freeway work zone crashes in general (or approximately 15 percent). In other words, efforts intended to reduce severe rear end collisions related to work zone congestion should not be exclusively focused on urban areas. The overwhelming majority of these collisions occurred during daylight hours (88.9 percent) and on dry pavement (90.0 percent). Truck involvement (42.0 percent) was in general agreement with the fatal crash experience as a whole in Michigan and nationally. Older driver involvement (31.1 percent) was greater than older driver involvement in fatal freeway work zone crashes in Michigan (15.9 percent) and nationally (17.9 percent). Impaired drivers represented a relatively small share (7.8 percent) of severe rear end collisions related to work zone congestion.

Severe rear end collisions related to work zone congestion are most commonly related to lane closures, where 11 of the 90 incidents occurred upstream of the first warning sign and 54 occurred in between the first and last warning signs. These collisions also commonly occur as a part of lane shifts or crossovers in between the first and last warning signs.

A total of 30 freeway work zone crashes involving pedestrians occurred during the six-year study period, including 14 incidents involving a road worker. These crashes are summarized in **Table 23** by circumstance.

Table 23. Freeway Work Zone Crashes Involving Pedestrians by Circumstance (2017-2022)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Workers Struck by Vehicle Entering Work Area	**10**	**33.3%**
	Worker Struck by Vehicle while Placing Traffic Control Devices	**2**	**6.7%**
	Worker Struck by Loose Object from Passing Vehicle	**1**	**3.3%**
	Worker Struck by Work Vehicle	**1**	**3.3%**
Other Crashes in Work Zone	Pedestrian Struck by Vehicle while Attempting to Cross Freeway	**6**	**20.0%**
	Pedestrian Struck by Vehicle while Walking along Shoulder	**4**	**13.3%**
	Pedestrian Struck after Prior Crash or Disabled Vehicle	**4**	**13.3%**
	Pedestrian Struck while Crossing at Ramp Crosswalk	**2**	**6.7%**
All Pedestrian-Involved Freeway Work Zone Crashes		**30**	**100.0%**

Ten crashes involved a worker struck by a vehicle entering the work area, representing the most common circumstance. Other scenarios included workers struck while placing traffic control (2), a worker struck by a loose object (1), and a worker struck by a work vehicle (1). Of these 14 incidents where a worker was struck while performing duties as a part of a freeway work zone:

- Eight crashes resulted in a fatality or serious injury to the worker or another involved party.
- Three crashes involved a driver that was impaired by alcohol and/or drugs.
- Nine crashes included the involvement of a large truck.
- Ten crashes occurred within an urban environment.
- Five crashes occurred in dark conditions (with or without lighting present).
- Six crashes involved mobile work or work on the shoulder or median.
- Twelve crashes occurred in between the first and last warning signs.

3.3.1 Mainline Freeway Work Zone Safety Performance

Further analysis was conducted to isolate the work zone safety performance observed along mainline freeway segments. A summary of work zone crashes occurring along mainline freeway segments only (excluding ramps or other segments that comprise complex interchanges) during the six-year study period is shown in **Table 24**.

Table 24. Mainline Freeway Work Zone Crashes by Severity and Crash Type (2017-2022)

Crash Type	Fatal (K)	Serious Injury (A)	Minor Injury (B)	Possible Injury (C)	PDO	All Severities
Single Vehicle	13	40	165	259	2,240	**2,717**
Head On	0	2	4	7	6	**19**
Head On Left-Turn	0	0	0	0	1	**1**
Angle	0	3	6	6	19	**34**
Rear End	30	88	314	1,088	4,798	**6,318**
Sideswipe Same	6	15	62	181	2,460	**2,724**
Sideswipe Opposite	0	0	0	2	15	**17**
Other/Unknown	11	4	29	51	338	**433**
All Crash Types	**60**	**152**	**580**	**1,594**	**9,877**	**12,263**

Approximately 93 percent of work zone crashes occurring along the freeway network are located on mainline segments (as opposed to ramp facilities), including 60 of the 63 fatal work zone crashes. The distribution of these 12,263 mainline freeway work zone collisions by crash type and work activity are presented in **Table 25**. Additionally, the distribution of these collisions by crash type and crash location are presented in **Table 26.**

Table 25. Distribution of Mainline Freeway Work Zone Crashes by Crash Type and Work Activity

Work Activity	Single Vehicle	Head On	Head On Left-Turn	Angle	Rear End	Side-swipe Same	Side-swipe Opp.	Other or Unknown
Lane Closure	10.7%	0.1%	0.0%	0.1%	34.6%	13.2%	0.1%	1.7%
Lane Shift or Crossover	5.3%	0.0%	0.0%	0.0%	7.2%	4.9%	0.0%	0.7%
Work on Shoulder or Median	3.5%	0.0%	0.0%	0.0%	5.3%	2.4%	0.0%	0.6%
Intermittent or Moving Work	0.8%	0.0%	0.0%	0.0%	1.7%	0.6%	0.0%	0.1%
Other/Unknown	1.8%	0.0%	0.0%	0.1%	2.6%	1.0%	0.0%	0.4%

Table 26. Distribution of Mainline Freeway Work Zone Crashes by Crash Type and Crash Location

Crash Location	Single Vehicle	Head On	Head On Left-Turn	Angle	Rear End	Sideswipe Same	Sideswipe Opposite	Other or Unknown
Before Warning Sign	0.8%	0.0%	0.0%	0.0%	4.5%	1.6%	0.0%	0.2%
Between Warning Signs	20.7%	0.1%	0.0%	0.2%	45.8%	20.1%	0.1%	3.3%
No Warning Signs	0.6%	0.0%	0.0%	0.0%	1.1%	0.6%	0.0%	0.1%
Other/Unknown	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%

Rear end collisions involving lane closures and occurring in between the first and last warning signs represent the most common crash scenario along mainline freeway segments. Single vehicle and sideswipe-same direction collisions occurring in between the first and last warning signs are also common and involve a mix of all work activities.

The distribution of mainline freeway work zone collisions by crash type is shown for mainline freeway segments located in both rural and urban environments in **Table 27**. Intuitively, single vehicle collisions are more common in rural environments (36.7 percent) than in urban environments (19.7). Conversely, rear end collisions are more common in urban environments (53.4 percent) than in rural environments (40.2 percent).

Table 27. Distribution of Mainline Freeway Work Zone Crashes by Crash Type and Area Type

Area Type	Single Vehicle	Head On	Head On Left-Turn	Angle	Rear End	Sideswipe Same	Sideswipe Opposite	Other or Unknown
Rural	36.7%	0.2%	0.0%	0.2%	40.2%	19.3%	0.1%	3.4%
Urban	19.7%	0.2%	0.0%	0.3%	53.4%	22.7%	0.1%	3.6%

3.3.2 Freeway Ramp Work Zone Safety Performance

In contrast to the analysis of mainline freeway segments, work zone crashes occurring along freeway ramps or other freeway segments that comprise complex interchanges represent only seven percent of all freeway network work zone collisions. A summary of work zone crashes occurring along freeway ramps only (or all other non-mainline freeway segments) during the six-year study period is shown in **Table 28**. It should be noted that the three fatal work zone crashes that occurred along freeway ramps included one rear end collision and two single vehicle lane departure collisions that were not directly related to the presence of a work zone.

Table 28. Freeway Ramp Work Zone Crashes by Severity and Crash Type (2017-2022)

Crash Type	Fatal (K)	Serious Injury (A)	Minor Injury (B)	Possible Injury (C)	PDO	All Severities
Single Vehicle	2	5	18	25	153	**203**
Head On	0	1	1	1	1	**4**
Head On Left-Turn	0	0	0	0	2	**2**
Angle	0	0	3	1	14	**18**
Rear End	1	1	11	60	308	**381**
Sideswipe Same	0	3	4	20	257	**284**
Sideswipe Opposite	0	0	0	1	3	**4**
Other/Unknown	0	2	3	4	33	**42**
All Crash Types	**3**	**12**	**40**	**112**	**771**	**938**

The sample of work zone ramp crashes did not include any workers struck by vehicles and the two pedestrian involved collisions occurred at the crosswalk ramps. This included one pedestrian struck while crossing during the DON'T WALK phase and one pedestrian struck by a vehicle failing to yield. As shown in **Figure 28**, rear end and sideswipe same-direction collisions are generally located at merge or diverge points, while single vehicle lane departure collisions can occur at any point along the facility.

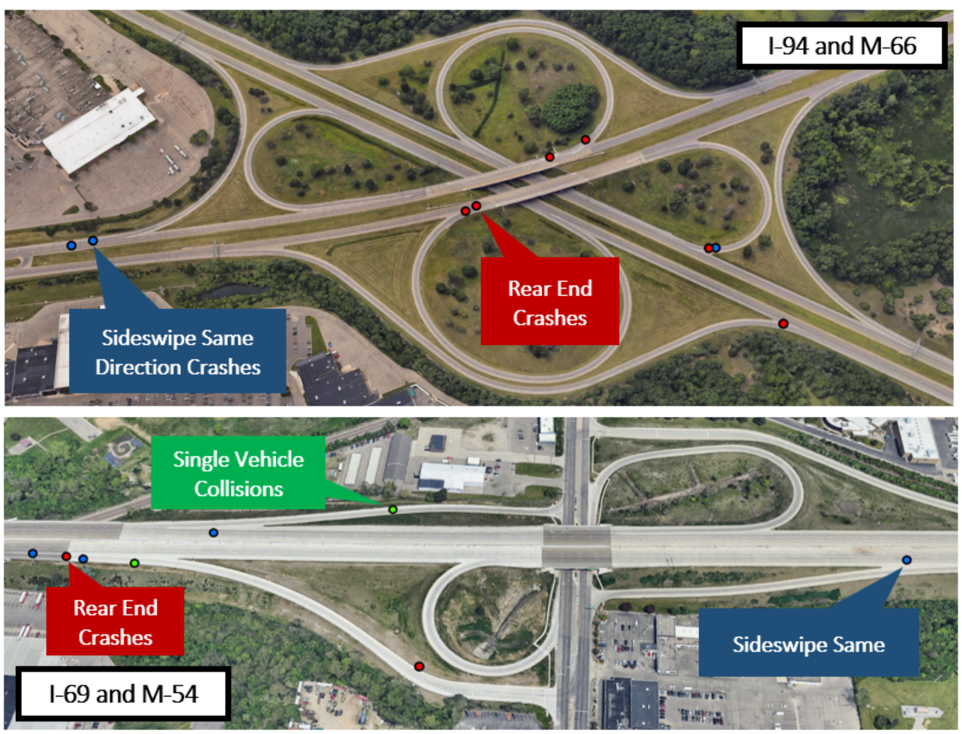


Figure 28. Common Freeway Ramp Work Zone Crash Locations

3.4 Statewide Non-Freeway Work Zone Safety Performance

A total of 17,698 work zone crashes occurred along Michigan's non-freeway network during the six-year study period, including 38 collisions resulting in a fatality (**Table 29**). As shown in **Figure 29**, non-freeway work zone crashes are widely distributed throughout the state where construction or maintenance activities have occurred during the study period.

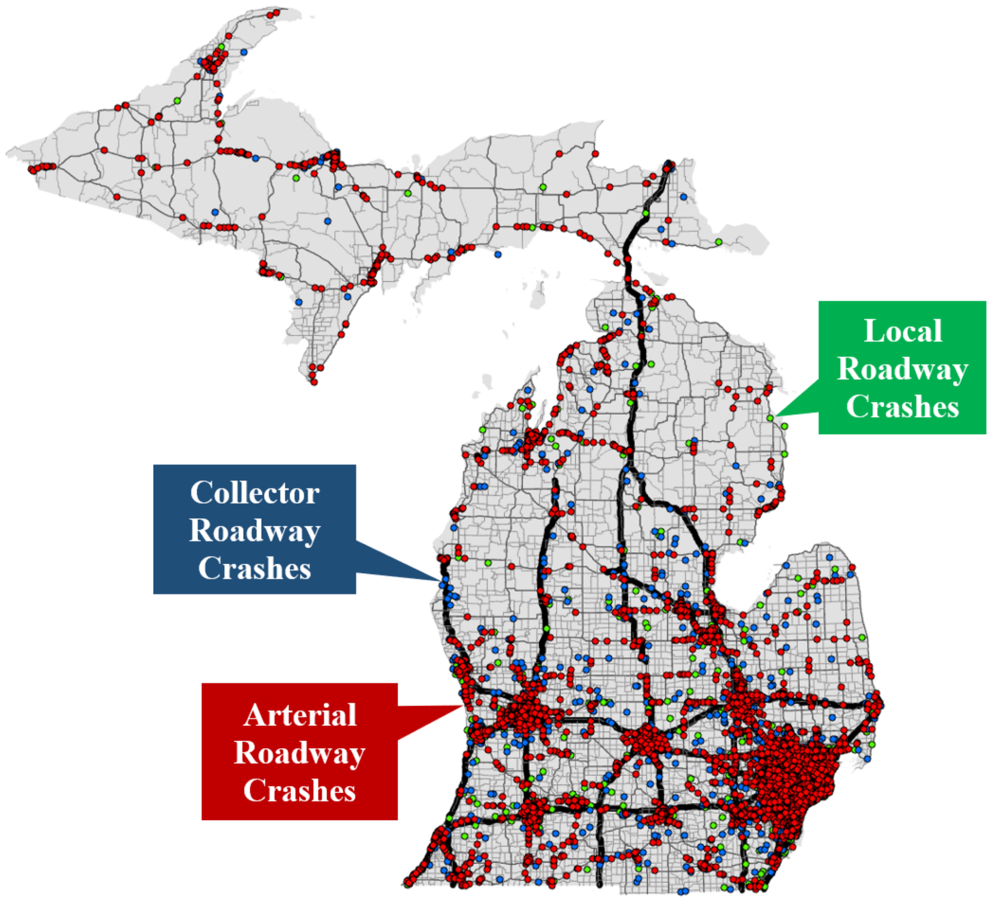


Figure 29. Non-Freeway Work Zone Traffic Crashes (2017-2022)

Table 29. Non-Freeway Work Zone Crashes by Severity and Crash Type (2017-2022)

Crash Type	Fatal (K)	Serious Injury (A)	Minor Injury (B)	Possible Injury (C)	PDO	All Severities
Single Vehicle	17	89	189	225	1,954	**2,474**
Head On	1	14	16	30	82	**143**
Head On Left-Turn	0	12	43	70	196	**321**
Angle	3	40	222	442	1,880	**2,587**
Rear End	11	41	322	1,238	5,792	**7,404**
Sideswipe Same	1	4	49	153	3,073	**3,280**
Sideswipe Opposite	0	7	11	16	265	**299**
Other/Unknown	5	16	35	71	1,063	**1,190**
All Crash Types	**38**	**223**	**887**	**2,245**	**14,305**	**17,698**

Construction or maintenance work zone crashes along the non-freeway network are most common along arterials where major projects have occurred (**Figure 30**). Work zone crashes along collectors primarily occur either adjacent to major work along arterials or where significant projects have occurred on the collector network. Work zone crashes along local roadways are generally located adjacent to major projects along higher classification routes (typically at minor intersections) and as isolated events where smaller projects have been completed to maintain the local roadway network.

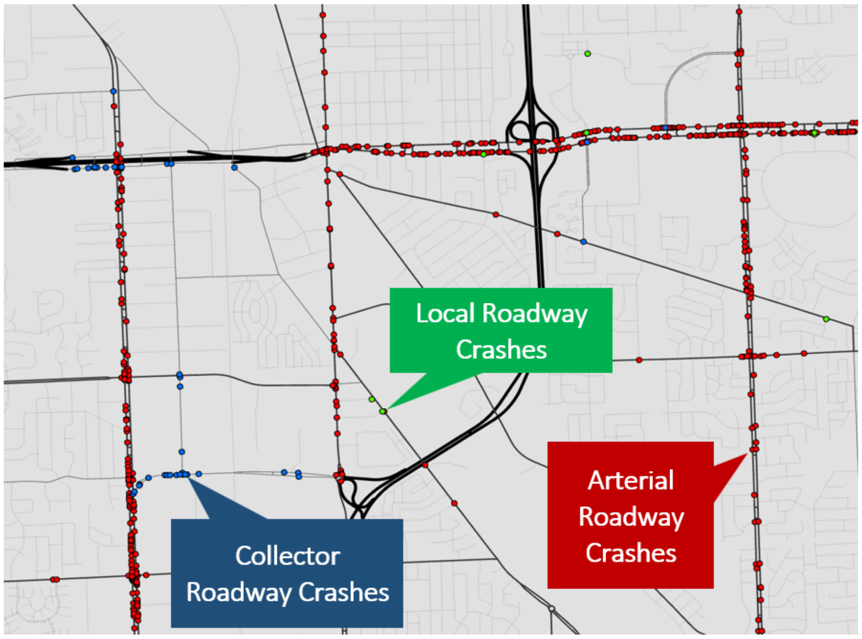


Figure 30. Example of Non-Freeway Work Zone Traffic Crashes by Roadway Type

Given that both the cycle of construction and maintenance work and the general function of these roadway types varies, work zone crash patterns also vary by roadway type (**Table 30**). Rear end collisions represent the predominate work zone crash type along arterial routes while single vehicle and other collisions become more common for collector and local roadways. More detailed information specific to each roadway type is provided in **Sections 3.4.1 – 3.4.3**.

Table 30. Distribution of Non-Freeway Work Zone Crashes by Roadway Type and Crash Type

Roadway Type	Single Vehicle	Head On	Head On Left-Turn	Angle	Rear End	Sideswipe Same	Sideswipe Opposite	Other or Unknown	All Crash Types
Arterial	12.1%	0.7%	1.9%	14.6%	45.2%	19.2%	1.4%	4.9%	**100.0%**
Collector	26.1%	1.1%	1.4%	13.7%	27.7%	15.7%	2.5%	11.7%	**100.0%**
Local	26.2%	1.4%	1.2%	16.3%	11.7%	12.4%	5.1%	25.6%	**100.0%**

3.4.1 Arterials

A total of 15,319 work zone collisions occurred along arterial routes during the six-year study period, including 29 fatal crashes and 184 serious injury crashes (**Table 31**). While these collisions are most common within urban areas, concentrations can be observed anywhere along the arterial network where significant projects have been completed (**Figure 31**).

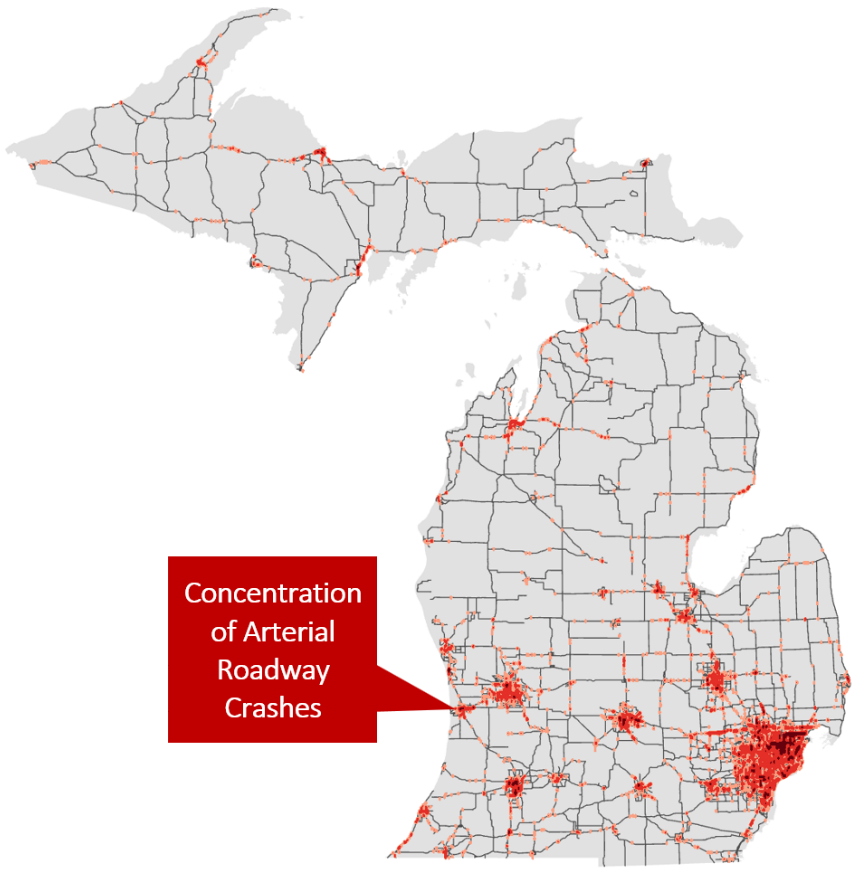


Figure 31. Concentrations of Arterial Roadway Work Zone Crashes (2017-2022)

Table 31. Arterial Work Zone Crashes by Severity and Crash Type (2017-2022)

Crash Type	Fatal (K)	Serious Injury (A)	Minor Injury (B)	Possible Injury (C)	PDO	All Severities
Single Vehicle	14	68	141	164	1,465	**1,852**
Head On	1	10	14	27	58	**110**
Head On Left-Turn	0	14	37	67	177	**295**
Angle	2	39	178	386	1,630	**2,235**
Rear End	8	37	291	1,168	5,420	**6,924**
Sideswipe Same	1	5	44	137	2,758	**2,945**
Sideswipe Opposite	0	5	9	15	179	**208**
Other/Unknown	3	6	26	63	652	**750**
All Crash Types	**29**	**184**	**740**	**2,027**	**12,339**	**15,319**

Similar to the findings specific to the freeway network (**Section 3.3**), Michigan has observed a higher share of fatal rear end work zone collisions (27.6 percent) along the arterial network compared to the national experience (12.6 percent), shown in **Table 32**. Additionally, Michigan has observed a higher share of fatal work zone crashes involving pedestrians along the arterial network (41.4 percent) than the national experience (16.0 percent), shown in **Table 33**.

Table 32. Michigan vs. National Fatal Arterial Work Zone Crashes by Crash Type

Location	Single Vehicle	Head-On	Angle	Rear-End	Sideswipe	Other
Michigan	48.3%	3.4%	6.9%	27.6%	3.4%	10.3%
National	52.2%	13.5%	18.3%	12.6%	2.7%	0.7%

Table 33. Michigan vs. National Fatal Arterial Work Zone Crashes by Category

Location	Truck	Motorcycle	Pedestrian	Bicyclist	Young Driver	Older Driver	Alcohol
Michigan	13.8%	13.8%	41.4%	3.4%	10.3%	24.1%	34.5%
National	19.2%	11.3%	16.0%	2.1%	8.9%	19.4%	27.7%

The distribution of all 15,319 arterial work zone collisions by crash type and work activity are presented in **Table 34**. Additionally, the distribution of these collisions by crash type and crash location are presented in **Table 35**.

Table 34. Distribution of Arterial Work Zone Crashes by Crash Type and Work Activity

Work Activity	Single Vehicle	Head On	Head On Left-Turn	Angle	Rear End	Side-swipe Same	Side-swipe Opp.	Other or Unknown
Lane Closure	7.1%	0.4%	1.3%	10.8%	34.4%	13.9%	0.9%	3.0%
Lane Shift or Crossover	1.4%	0.1%	0.3%	1.7%	5.0%	2.9%	0.2%	0.6%
Work on Shoulder or Median	1.6%	0.1%	0.1%	0.7%	2.6%	0.8%	0.1%	0.5%
Intermittent or Moving Work	0.5%	0.0%	0.0%	0.5%	1.4%	0.6%	0.0%	0.4%
Other/Unknown	1.5%	0.1%	0.2%	0.9%	1.9%	0.9%	0.1%	0.5%

Table 35. Distribution of Arterial Work Zone Crashes by Crash Type and Crash Location

Crash Location	Single Vehicle	Head On	Head On Left-Turn	Angle	Rear End	Side-swipe Same	Side-swipe Opp.	Other or Unknown
Before Warning Sign	0.7%	0.1%	0.2%	0.9%	4.2%	2.1%	0.1%	0.5%
Between Warning Signs	10.0%	0.5%	1.5%	12.4%	37.9%	15.5%	1.2%	3.8%
No Warning Signs	1.3%	0.1%	0.3%	1.3%	3.1%	1.6%	0.1%	0.6%
Other/Unknown	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%

Rear end collisions involving lane closures and occurring in between the first and last warning signs represent the most common crash scenario along the arterial network. Single vehicle, angle, and sideswipe same-direction collisions involving lane closures and occurring in between the first and last warning signs are also common.

A total of 213 fatal and serious injury work zone crashes occurred along Michigan's arterial network during the six-year study period, shown in **Table 36** by the circumstance obtained from the UD-10 crash report form review. While any collision that occurs within a work zone could be related to the presence of work zone traffic control, workers, work vehicles, or equipment, **Table 36** identifies the subset of fatal and serious injury work zone crashes that were directly related to the presence of a work zone.

Table 36. Summary of Fatal and Serious Injury Arterial Work Zone Crashes (2017-2022)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Rear End Collision Related to Work Zone Presence	33	15.5%
	Workers, Work Vehicles, or Equipment Struck by Vehicle	15	7.0%
	Single Vehicle Collisions Related to Work Zone	8	3.8%
	Motorcycle Loss of Control Related to Work Zone	11	5.2%
	Head On Left Turn or Angle Collisions Related to Work Zone Presence	12	5.6%
	Work Vehicle Struck Workers or Other Vehicles	4	1.9%
	Other Circumstances Related to Work Zone Presence	5	2.3%
Other Motor Vehicle Crashes in Work Zone	Collision Due to Lane Departure or Loss of Control	28	13.1%
	Pedestrian or Bicyclist Struck by Vehicle while Attempting to Cross Midblock	13	6.1%
	Pedestrian or Bicyclist Struck while Traveling on Roadway	6	2.8%
	Pedestrian Struck by Vehicle within Crosswalk	4	1.9%
	Collisions Related to Red Light Running	14	6.6%
	Other Head On Left Turn/Angle Collisions Not Directly Related to Work Zone	27	12.7%
	Head On or Sideswipe Opposite Collisions Not Directly Related to Work Zone	7	3.3%
	Rear End Collision Not Directly Related to Work Zone Presence	8	3.8%
	Driver Fell Asleep or Had Medical Emergency	5	2.3%
	Other Circumstances Not Directly Related to Work Zone Presence	13	6.1%
All Fatal (K) and Serious (A) Injury Arterial Work Zone Crashes		**213**	**100.0%**

Approximately 41 percent of severe work zone collisions occurring within an arterial work zone were directly related to the presence of work zone traffic control, workers, work vehicles, or equipment. Rear end collisions related to the presence of a work zone (15.5 percent) represent the most common circumstance during the six-year study period. While such rear end collisions remain a critical safety issue for arterial routes, it should be noted that both the frequency (33 vs. 90) and share (15.5 percent vs. 39.6 percent) of these collisions were smaller for the arterial network compared to the freeway network. Workers, work vehicles, or equipment struck by a vehicle (15), single vehicle collisions involving work zone traffic control or pavement conditions (8), motorcyclists losing control due to work zone traffic control or temporary pavement conditions (11), and head on left turn or angle collisions related to the presence of work zone traffic control (12) were other common circumstances.

A total of 154 arterial work zone crashes involving pedestrians or bicyclists occurred during the six-year study period, including 57 incidents involving a road worker being struck by a vehicle. These crashes are summarized in **Table 37** by circumstance.

Table 37. Summary of Arterial Work Zone Crashes involving Pedestrians and Bicyclists (2017-2022)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Flagger or Other Worker Struck by Vehicle that Disregarded Flagger Control	**21**	**13.6%**
	Worker Struck by Vehicle Entering Work Area for Other Reason	**31**	**20.1%**
	Worker Struck by Work Vehicle	**4**	**2.6%**
	Worker Struck by Vehicle while Placing Traffic Control Devices	**1**	**0.6%**
	Bicyclist Struck by Vehicle while Interacting with Channelizing Devices	**3**	**1.9%**
	Other Circumstance Related to Work Zone Presence	**6**	**3.9%**
Other Crashes in Work Zone	Pedestrian Struck while Attempting to Cross Midblock	**23**	**14.9%**
	Bicyclist Struck while Attempting to Cross Midblock	**8**	**5.2%**
	Pedestrian Struck while Walking on Roadway	**6**	**3.9%**
	Bicyclist Struck by Vehicle on Roadway	**8**	**5.2%**
	Pedestrian Struck while in Crosswalk	**10**	**6.5%**
	Pedestrian Struck while Crossing during Don't Walk Phase	**5**	**3.2%**
	Bicyclist Struck while in Crosswalk	**9**	**5.8%**
	Bicyclist Struck After Failing to Yield at Intersection	**5**	**3.2%**
	Other Circumstance Not Related to Work Zone Presence	**14**	**9.1%**
All Pedestrian-Involved and Bicycle-Involved Arterial Work Zone Crashes		**154**	**100.0%**

A key safety concern for arterial work zones is the interaction between flaggers and the driving public, where 21 collisions occurred that involved a vehicle striking either a flagger or disregarding flagger control and striking another road worker. A total of 31 crashes involved a worker struck by a vehicle entering the work area for a reason other than disregarding flagger control. The 57 incidents involving road workers along arterials is notable in contrast to the 14 incidents that occurred along the freeway network during the same six-year study period. Of these 57 incidents involving road workers:

- 11 crashes resulted in a fatality or serious injury to the worker or another involved party.
- 53 crashes occurred during daylight hours.
- The majority of these crashes occurred as a part of lane closures (33), with work on the shoulder or median (10) and moving work (7) being the next most common.
- Seven crashes occurred with no warning signs present.

There were also three incidents involving a bicyclist being struck by a vehicle while traveling on the roadway and attempting to navigate work zone channelizing devices.

3.4.2 Collectors

A total of 1,270 work zone collisions occurred along collector routes during the six-year study period, including 8 fatal crashes and 22 serious injury crashes (**Table 38**). These collisions are more widely distributed across the state compared to the arterial work zone experience summarized in **Section 3.4.1**, where concentrations of collector work zone crashes can be observed across the state anywhere that projects have occurred during the six-year study period (**Figure 32**).

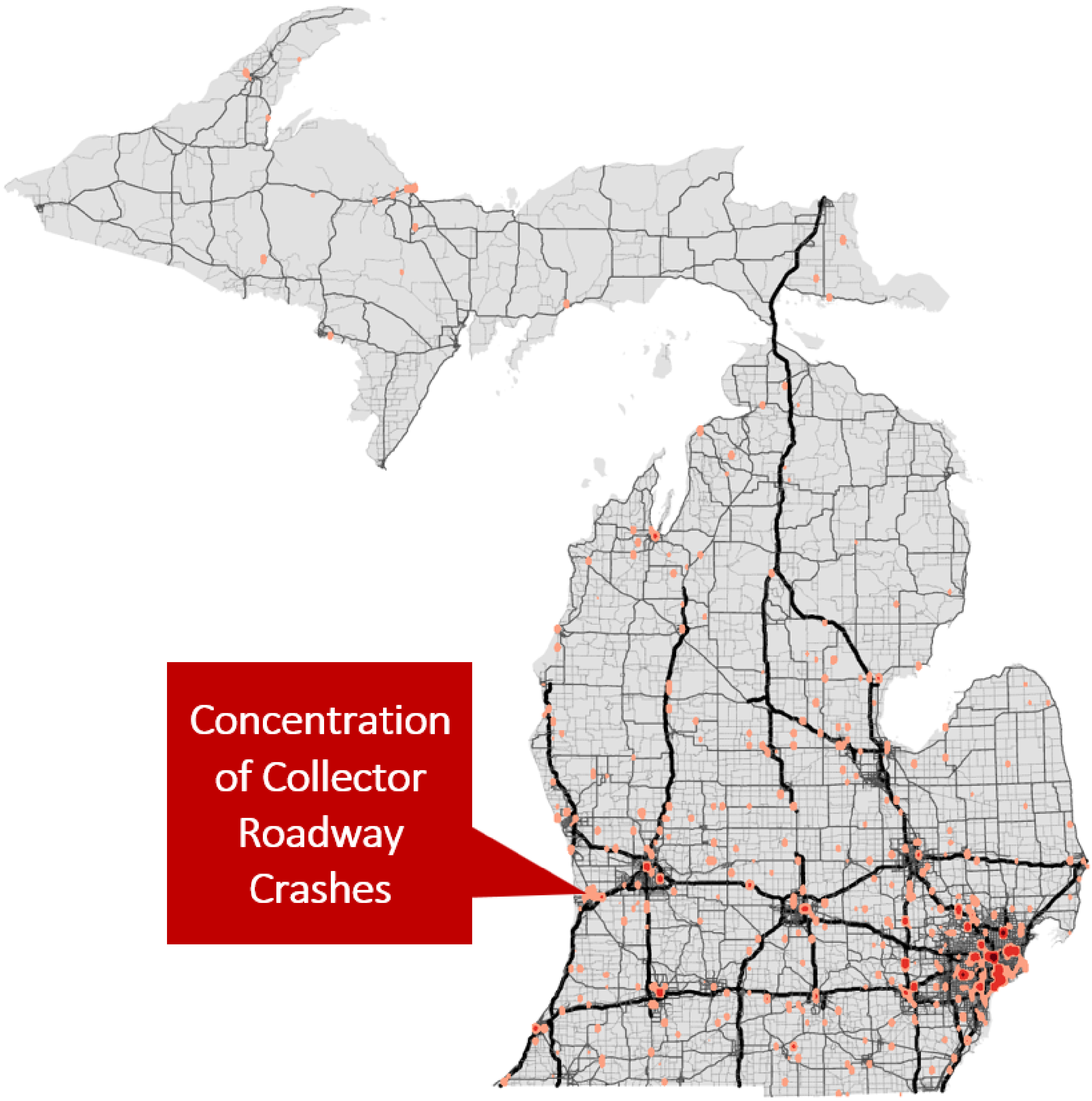


Figure 32. Concentrations of Collector Roadway Work Zone Crashes (2017-2022)

Table 38. Collector Work Zone Crashes by Severity and Crash Type (2017-2022)

Crash Type	Fatal (K)	Serious Injury (A)	Minor Injury (B)	Possible Injury (C)	PDO	All Severities
Single Vehicle	2	11	30	35	253	**331**
Head On	0	1	1	2	10	**14**
Head On Left-Turn	0	1	4	1	12	**18**
Angle	1	1	32	31	109	**174**
Rear End	3	5	25	57	262	**352**
Sideswipe Same	0	1	3	7	189	**200**
Sideswipe Opposite	0	0	2	1	29	**32**
Other/Unknown	2	2	7	5	133	**149**
All Crash Types	**8**	**22**	**104**	**139**	**997**	**1,270**

The distribution of all 1,270 collector work zone collisions by crash type and work activity are presented in **Table 39**. Additionally, the distribution of these collisions by crash type and crash location are presented in **Table 40**.

Table 39. Distribution of Collector Work Zone Crashes by Crash Type and Work Activity

Work Activity	Single Vehicle	Head On	Head On Left-Turn	Angle	Rear End	Side-swipe Same	Side-swipe Opp.	Other or Unknown
Lane Closure	11.6%	0.7%	1.0%	8.7%	16.1%	9.7%	1.0%	6.1%
Lane Shift or Crossover	1.8%	0.0%	0.0%	1.7%	3.5%	1.8%	0.3%	0.8%
Work on Shoulder or Median	4.2%	0.1%	0.0%	0.9%	2.4%	1.3%	0.8%	1.1%
Intermittent or Moving Work	1.7%	0.1%	0.2%	0.9%	2.5%	1.1%	0.2%	1.7%
Other/Unknown	6.9%	0.2%	0.2%	1.6%	3.2%	1.8%	0.2%	2.0%

Table 40. Distribution of Collector Work Zone Crashes by Crash Type and Crash Location

Crash Location	Single Vehicle	Head On	Head On Left-Turn	Angle	Rear End	Side-swipe Same	Side-swipe Opp.	Other or Unknown
Before Warning Sign	1.6%	0.2%	0.3%	1.3%	2.8%	1.3%	0.1%	1.5%
Between Warning Signs	19.2%	0.8%	0.9%	9.4%	20.9%	11.9%	1.9%	7.0%
No Warning Signs	5.0%	0.1%	0.2%	2.8%	4.1%	2.4%	0.6%	3.1%
Other/Unknown	0.2%	0.0%	0.0%	0.2%	0.0%	0.1%	0.0%	0.1%

In contrast with the findings for mainline freeways and arterial roadways, rear end collisions comprise a far smaller share of all collector work zone crashes. The share of single vehicle collisions is considerably higher for collector roadways than for arterials, principally occurring either between the first and last warning signs and where no warning signs are present.

A total of 30 fatal and serious injury work zone crashes occurred along Michigan's collector network during the six-year study period, shown in **Table 41** by the circumstance obtained from the UD-10 crash report form review. While any collision that occurs within a work zone could be related to the presence of work zone traffic control, workers, work vehicles, or equipment, **Table 41** identifies the subset of fatal and serious injury work zone crashes that were directly related to the presence of a work zone.

Table 41. Summary of Fatal and Serious Injury Collector Work Zone Crashes (2017-2022)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Rear End Collision Related to Work Zone Presence	6	20.0%
	Workers, Work Vehicles, or Equipment Struck by Vehicle	5	16.7%
	Single Vehicle Collisions Related to Work Zone	6	20.0%
	Motorcycle Loss of Control Related to Work Zone	3	10.0%
	Other Circumstances Related to Work Zone Presence	1	3.3%
Other Motor Vehicle Crashes in Work Zone	Collision Due to Lane Departure or Loss of Control	4	13.3%
	Collisions Related to Red Light Running	1	3.3%
	Other Head On Left Turn/Angle Collisions Not Directly Related to Work Zone	2	6.7%
	Rear End Collision Not Directly Related to Work Zone Presence	1	3.3%
	Other Circumstances Not Directly Related to Work Zone Presence	1	3.3%
All Fatal (K) and Serious (A) Injury Collector Work Zone Crashes		**30**	**100.0%**

Approximately 70 percent of severe work zone collisions occurring within a collector work zone were directly related to the presence of work zone traffic control, workers, work vehicles, or equipment. Consistent with the arterial work zone experience, rear end collisions related to the presence of a work zone represent one-fifth of all severe collector work zone crashes. Workers, work vehicles, or equipment struck by a vehicle (5), single vehicle collisions involving work zone traffic control or pavement conditions (6), and motorcyclists losing control due to work zone traffic control or temporary pavement conditions (3) were other common circumstances.

A total of 34 collector work zone crashes involving pedestrians or bicyclists occurred during the six-year study period, including 23 incidents involving a road worker being struck by a vehicle. These crashes are summarized in **Table 42** by circumstance.

Table 42. Summary of Collector Work Zone Crashes involving Pedestrians and Bicyclists (2017-2022)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Flagger or Other Worker Struck by Vehicle that Disregarded Flagger Control	17	50.0%
	Worker Struck by Vehicle Entering Work Area for Other Reason	5	14.7%
	Worker Struck by Vehicle while Placing Traffic Control Devices	1	2.9%
	Bicyclist Struck by Vehicle while Interacting with Channelizing Devices	1	2.9%
	Other Circumstance Related to Work Zone Presence	1	2.9%
Other Crashes in Work Zone	Bicyclist Struck while Attempting to Cross Midblock	1	2.9%
	Bicyclist Struck by Vehicle on Roadway	3	8.8%
	Pedestrian Struck while in Crosswalk	2	5.9%
	Bicyclist Struck while in Crosswalk	1	2.9%
	Other Circumstance Not Related to Work Zone Presence	2	5.9%
All Pedestrian-Involved and Bicycle-Involved Collector Work Zone Crashes		**34**	**100.0%**

A key safety concern for collector work zones remains the interaction between flaggers and the driving public, where 17 collisions occurred that involved a vehicle striking either a flagger or disregarding flagger control and striking another road worker.

3.4.3 Local Roadways

A total of 1,109 work zone collisions occurred along local roadways during the six-year study period, including one fatal crash and 17 serious injury crashes (**Table 43**). Local roadway work zone crashes are commonly located within urban areas but can be observed across the state anywhere that projects have occurred during the six-year study period (**Figure 33**).

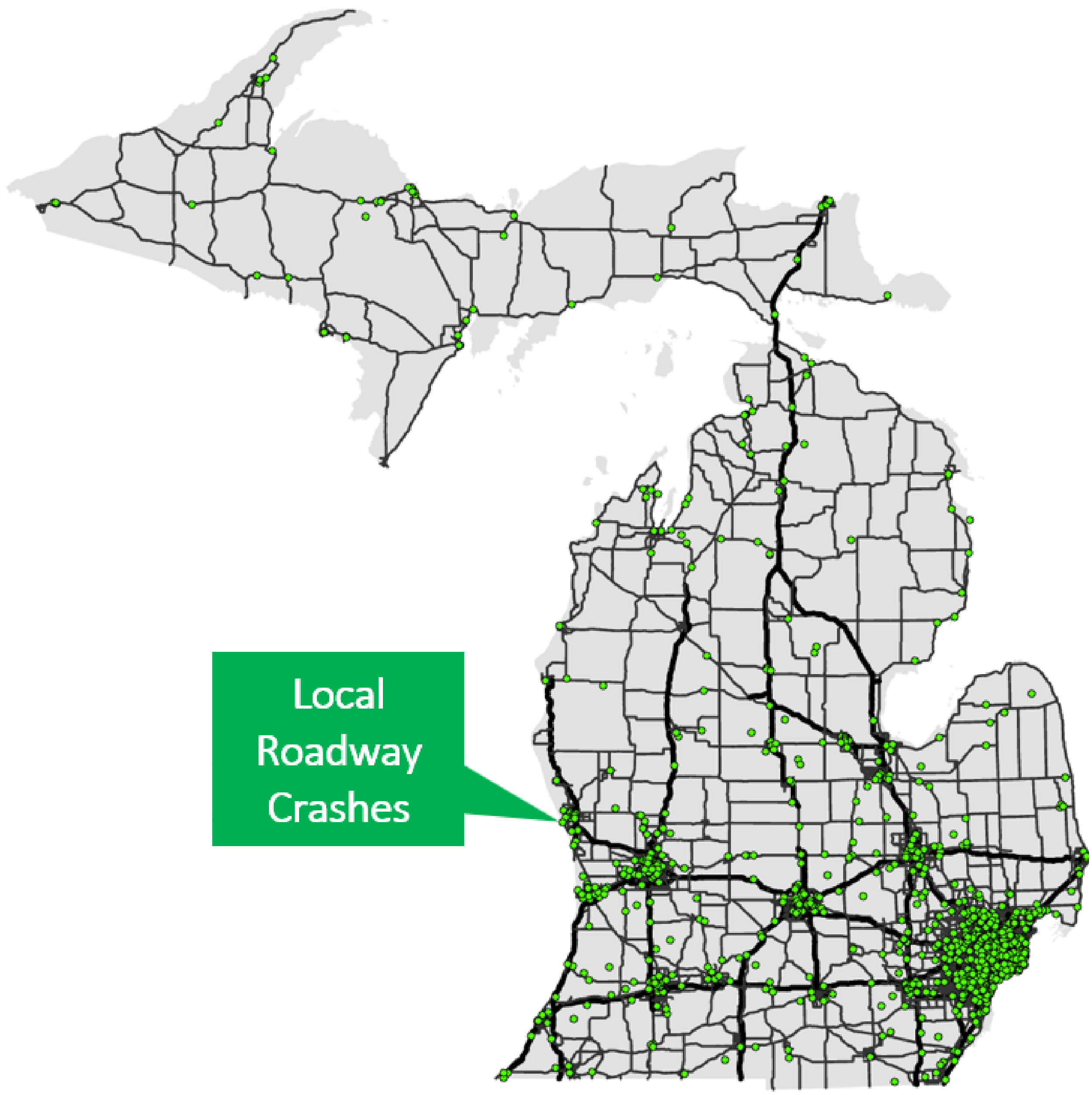


Figure 33. Local Roadway Work Zone Traffic Crashes (2017-2022)

Table 43. Local Roadway Work Zone Crashes by Severity and Crash Type (2017-2022)

Crash Type	Fatal (K)	Serious Injury (A)	Minor Injury (B)	Possible Injury (C)	PDO	All Severities
Single Vehicle	1	10	18	26	236	**291**
Head On	0	0	1	1	14	**16**
Head On Left-Turn	0	2	2	2	7	**13**
Angle	0	3	12	25	141	**181**
Rear End	0	1	6	13	110	**130**
Sideswipe Same	0	0	2	9	126	**137**
Sideswipe Opposite	0	0	0	0	57	**57**
Other/Unknown	0	1	2	3	278	**284**
All Crash Types	**1**	**17**	**43**	**79**	**969**	**1,109**

The distribution of all 1,109 local roadway work zone collisions by crash type and work activity are presented in **Table 44**. Additionally, the distribution of these collisions by crash type and crash location are presented in **Table 45**.

Table 44. Distribution of Local Work Zone Crashes by Crash Type and Work Activity

Work Activity	Single Vehicle	Head On	Head On Left-Turn	Angle	Rear End	Side-swipe Same	Side-swipe Opp.	Other or Unknown
Lane Closure	11.9%	0.6%	0.7%	9.1%	5.6%	3.8%	1.9%	7.5%
Lane Shift or Crossover	1.6%	0.1%	0.0%	1.3%	1.4%	1.0%	0.2%	0.9%
Work on Shoulder or Median	2.6%	0.1%	0.1%	1.4%	1.2%	1.4%	0.5%	3.6%
Intermittent or Moving Work	3.2%	0.4%	0.1%	1.4%	2.1%	2.6%	0.6%	5.3%
Other/Unknown	6.9%	0.3%	0.3%	3.2%	1.5%	3.5%	2.0%	8.3%

Table 45. Distribution of Local Work Zone Crashes by Crash Type and Crash Location

Crash Location	Single Vehicle	Head On	Head On Left-Turn	Angle	Rear End	Side-swipe Same	Side-swipe Opp.	Other or Unknown
Before Warning Sign	1.9%	0.1%	0.1%	1.2%	1.5%	0.9%	0.4%	2.4%
Between Warning Signs	16.6%	0.7%	0.8%	11.5%	6.7%	5.6%	2.6%	12.2%
No Warning Signs	7.5%	0.6%	0.3%	3.5%	3.5%	5.6%	2.2%	10.9%
Other/Unknown	0.3%	0.0%	0.0%	0.1%	0.0%	0.3%	0.0%	0.1%

In contrast with all of the other roadway types evaluated in this study, rear end collisions are not the predominant work zone crash type along local roadways. Instead, single vehicle, angle, and other collisions occurring in between the first and last warning signs or where no warning signs are present represent the most common crash type across a mix of work activities.

A total of 18 fatal and serious injury work zone crashes occurred along Michigan's local roadway network during the six-year study period, shown in **Table 46** by the circumstance obtained from the UD-10 crash report form review. While any collision that occurs within a work zone could be related to the presence of work zone traffic control, workers, work vehicles, or equipment, **Table 46** identifies the subset of fatal and serious injury work zone crashes that were directly related to the presence of a work zone.

Table 46. Summary of Fatal and Serious Injury Local Work Zone Crashes (2017-2022)

Circumstance		Count	Share
Common W.Z. Crash Scenarios	Workers, Work Vehicles, or Equipment Struck by Vehicle	**5**	**27.8%**
	Head On Left Turn or Angle Collisions Related to Work Zone Presence	**1**	**5.6%**
	Work Vehicle Struck Workers or Other Vehicles	**2**	**11.1%**
Other Motor Vehicle Crashes in Work Zone	Collision Due to Lane Departure or Loss of Control	**2**	**11.1%**
	Pedestrian or Bicyclist Struck by Vehicle while Attempting to Cross Midblock	**1**	**5.6%**
	Pedestrian or Bicyclist Struck while Traveling on Roadway	**1**	**5.6%**
	Pedestrian Struck by Vehicle within Crosswalk	**1**	**5.6%**
	Other Head On Left Turn/Angle Collisions Not Directly Related to Work Zone	**4**	**22.2%**
	Other Circumstances Not Directly Related to Work Zone Presence	**1**	**5.6%**
All Fatal (K) and Serious (A) Injury Local Work Zone Crashes		**18**	**100.0%**

Approximately 44 percent of severe work zone collisions occurring within a local roadway work zone were directly related to the presence of work zone traffic control, workers, work vehicles, or equipment. It should be noted that there were no rear end collisions related to the presence of a work zone along local roadways during the study period. Workers, work vehicles, or equipment struck by a vehicle (5), work vehicles striking workers or other vehicles (2), and head on left turn or angle collisions (1) were other work zone-related circumstances.

A total of 29 local roadway work zone crashes involving pedestrians or bicyclists occurred during the six-year study period, including 19 incidents involving a road worker being struck by a vehicle. These crashes are summarized in **Table 47** by circumstance.

Table 47. Summary of Local Work Zone Crashes involving Pedestrians and Bicyclists (2017-2022)

Circumstance		Count	Share
Common W.Z. Crash Scenarios	Flagger Other Worker Struck by Vehicle that Disregarded Flagger Control	**6**	**20.7%**
	Worker Struck by Vehicle Entering Work Area for Other Reason	**11**	**37.9%**
	Worker Struck by Work Vehicle	**2**	**6.9%**
Other Crashes in Work Zone	Pedestrian Struck while Attempting to Cross Midblock	**2**	**6.9%**
	Pedestrian Struck while Walking on Roadway	**1**	**3.4%**
	Bicyclist Struck by Vehicle on Roadway	**1**	**3.4%**
	Pedestrian Struck while in Crosswalk	**1**	**3.4%**
	Bicyclist Struck while in Crosswalk	**1**	**3.4%**
	Bicyclist Struck After Failing to Yield at Intersection	**4**	**13.8%**
All Pedestrian-Involved and Bicycle-Involved Local Roadway Work Zone Crashes		**29**	**100.0%**

Consistent with the findings for arterial and collector roadways, a key safety concern for local roadway work zones is the interaction between flaggers and the driving public, where 6 collisions occurred that involved a vehicle striking either a flagger or disregarding flagger control and striking another road worker. A notable difference from the evaluation of collector roadways was the frequency of workers struck by a vehicle entering the work area for another reason (11), which was considerably higher than the frequency of these incidents on collector roadways (5). Among these 11 collisions:

- Four resulted in a serious (A) injury.
- Seven occurred with no warning signs present.
- Five occurred as a part of intermittent or mobile work activities.
- Zero involved alcohol or drugs.
- All eleven occurred during daylight hours in dry conditions.

3.5 Summary of Findings

Given the objective to identify the work zone attributes related to safety performance and identify cost effective treatments, this effort provides a roadmap to target statewide work zone crash patterns or circumstances in order to accelerate progress towards MDOT's long-term zero death vision [*271*]. A detailed analysis of historical Michigan traffic crash data specific to highway work zones was conducted for the six-year period between 2017 and 2022. A summary of the key findings from **Sections 3.2 to 3.4** are summarized in **Table 48** that identify statewide work zone safety performance trends that represent potential areas for improvement.

Table 48. Summary of Findings by Roadway Type

Roadway Type	Finding
All Roadway Types	• Michigan has experienced an annual average of approximately 5,150 construction or maintenance work zone-coded traffic crashes per year, including approximately 17 collisions resulting in a fatality and 65 collisions resulting in a serious injury. • Statewide work zone-coded crash totals are less sensitive to overall travel trends compared to total crash frequency. Instead, statewide work zone-coded crash totals are largely driven by the amount of roadwork conducted in any given year. • Work zone-coded crashes in Michigan are principally comprised of rear end collisions (45.6 percent), sideswipe same-direction collisions (20.4 percent), and single vehicle collisions (17.5 percent). Head on (0.5 percent), head on left-turn (1.1 percent), and sideswipe opposite-direction (1.0 percent) work zone collisions are relatively rare. • When compared to the national experience, Michigan tends to observe a larger proportion of rear end work zone collisions and a smaller proportion of single vehicle collisions. • Approximately one third of work zone collisions in Michigan occur when workers are present. • Lane closures are by far the most common work activity associated with work zone traffic crashes (65.0 percent), followed by lane shifts or crossovers (14.5 percent) and work on the shoulder or in the median (9.2 percent). • The overwhelming majority (84.6 percent) of work zone collisions occur between the first and last warning signs, including approximately three-quarters of all fatal work zone collisions. • Fatal and serious injury work zone collisions become more common in dark conditions with or without lighting present.
Freeways	• Michigan has experienced an annual average of approximately 2,200 freeway work zone-coded traffic crashes per year, including approximately 11 collisions resulting in a fatality and 27 collisions resulting in a serious injury. • Nearly half of fatal freeway work zone crashes in Michigan are rear end collisions, compared to approximately one-third of fatal work zone crashes nationwide. • More than half of the 227 severe work zone crashes (56.8 percent) were directly related to the presence of work zone traffic control, workers, work vehicles, or equipment.

<table>
<tr><th>Roadway Type</th><th>Finding</th></tr>
<tr><td></td><td>

Rear end collisions related to work zone congestion (39.6 percent) represent the most common circumstance leading to fatalities or serious injuries.

While the majority of these collisions occur in urban environments (71.1 percent), it should be noted that the 28.9 percent occurring in rural environments represents a higher share than rural freeway work zone crashes in general (or approximately 15 percent).
The overwhelming majority of these collisions occurred during daylight hours (88.9 percent) and on dry pavement (90.0 percent).
These collisions are most commonly related to lane closures, where 11 of the 90 incidents occurred upstream of the first warning sign and 54 occurred in between the first and last warning signs.

A total of 30 freeway work zone crashes involving pedestrians occurred during the six-year study period, including 14 incidents involving a road worker. Ten of these collisions involved a worker struck by a vehicle entering the work area.
Approximately 93 percent of freeway work zone crashes are located on mainline segments (as opposed to ramp facilities), including 60 of the 63 fatal work zone crashes, where:

Rear end collisions involving lane closures and occurring in between the first and last warning signs represent the most common crash scenario.
Single vehicle and sideswipe-same direction collisions occurring in between the first and last warning signs are also common and involve a mix of all work activities.
Single vehicle collisions are more common in rural environments (36.7 percent) than in urban environments (19.7). Conversely, rear end collisions are more common in urban environments (53.4 percent) than in rural environments (40.2 percent).

Work zone crashes occurring along freeway ramps or other freeway segments that comprise complex interchanges represent only seven percent of all freeway work zone collisions.

The three fatal work zone crashes that occurred along freeway ramps included one rear end collision and two single vehicle lane departure collisions that were not directly related to the presence of a work zone.

</td></tr>
<tr><td>Arterials</td><td>

Michigan has experienced an annual average of approximately 2,553 arterial work zone-coded traffic crashes per year, including approximately 5 collisions resulting in a fatality and 31 collisions resulting in a serious injury.
Michigan has observed a higher share of fatal rear end work zone collisions (27.6 percent) compared to the national experience (12.6 percent).
Michigan has observed a higher share of fatal work zone crashes involving pedestrians (41.4 percent) than the national experience (16.0 percent).

</td></tr>
</table>

Roadway Type	Finding

	• Rear end collisions involving lane closures and occurring in between the first and last warning signs represent the most common crash scenario.
	• Single vehicle, angle, and sideswipe same-direction collisions involving lane closures and occurring in between the first and last warning signs are also common.
	• Approximately 41 percent of the 213 severe work zone crashes were directly related to the presence of work zone traffic control, workers, work vehicles, or equipment.
	  o Rear end collisions related to the presence of a work zone (33) represent the most common circumstance during the six-year study period.
	  o Workers, work vehicles, or equipment struck by a vehicle (15), single vehicle collisions involving work zone traffic control or pavement conditions (8), motorcyclists losing control due to work zone traffic control or temporary pavement conditions (11), and head on left turn or angle collisions related to the presence of work zone traffic control (12) were other common circumstances.
	• A total of 154 arterial work zone crashes involving pedestrians or bicyclists occurred during the six-year study period, including 57 incidents involving a road worker being struck by a vehicle.
	  o A key safety concern is the interaction between flaggers and the driving public, where 21 collisions occurred that involved a vehicle striking either a flagger or disregarding flagger control and striking another road worker.
	  o The 57 incidents involving road workers along arterials is notable in contrast to the 14 incidents that occurred along the freeway network during the same six-year study period.

Collectors	• Michigan has experienced an annual average of approximately 212 collector work zone-coded traffic crashes per year, including approximately 1.3 collisions resulting in a fatality and 3.7 collisions resulting in a serious injury. • In contrast with the findings for mainline freeways and arterial roadways, rear end collisions comprise a far smaller share of all collector work zone crashes. • The share of single vehicle collisions is considerably higher for collector roadways than for arterials, principally occurring either between the first and last warning signs and where no warning signs are present. • Approximately 70 percent of severe work zone collisions were directly related to the presence of work zone traffic control, workers, work vehicles, or equipment. o Consistent with the arterial work zone experience, rear end collisions related to the presence of a work zone represent one-fifth of all severe collector work zone crashes.

Roadway Type	Finding
	o Workers, work vehicles, or equipment struck by a vehicle (5), single vehicle collisions involving work zone traffic control or pavement conditions (6), and motorcyclists losing control due to work zone traffic control or temporary pavement conditions (3) were other common circumstances. • A total of 34 collector work zone crashes involving pedestrians or bicyclists occurred during the six-year study period, including 23 incidents involving a road worker being struck by a vehicle. o A key safety concern for collector work zones remains the interaction between flaggers and the driving public, where 17 collisions occurred that involved a vehicle striking either a flagger or disregarding flagger control and striking another road worker.
Local Roadways	• Michigan has experienced an annual average of approximately 185 local roadway work zone-coded traffic crashes per year, including approximately 0.17 collisions resulting in a fatality and 2.8 collisions resulting in a serious injury. • In contrast with all of the other roadway types evaluated in this study, rear end collisions are not the predominant work zone crash type along local roadways. • Instead, single vehicle, angle, and other collisions occurring in between the first and last warning signs or where no warning signs are present represent the most common crash type across a mix of work activities. • Approximately 44 percent of severe work zone collisions were directly related to the presence of work zone traffic control, workers, work vehicles, or equipment. o It should be noted that there were no rear end collisions related to the presence of a work zone along local roadways during the six-year study period. o Workers, work vehicles, or equipment struck by a vehicle (5), work vehicles striking workers or other vehicles (2), and head on left turn or angle collisions related to the presence of a work zone (1) were other circumstances. • A total of 29 work zone crashes involving pedestrians or bicyclists occurred during the six-year study period, including 19 incidents involving a road worker being struck by a vehicle. o A key safety concern for local roadway work zones is the interaction between flaggers and the driving public, where 6 collisions occurred that involved a vehicle striking either a flagger or disregarding flagger control and striking another road worker. o A notable difference from the evaluation of collector roadways was the frequency of workers struck by a vehicle entering the work area for another reason (11), which was considerably higher than the frequency of these incidents on collector roadways (5).

4.0 DETAILED SAFETY PERFORMANCE ANALYSIS OF SELECT FREEWAY WORK ZONES IN MICHIGAN

Historical models were developed of 25 recent freeway work zones across the state of Michigan in order to evaluate the safety and mobility impacts of implementing temporary traffic control to complete long-term construction projects. The goal was to conduct a detailed analysis of historical traffic crash data specific to highway work zones in order to quantify potential trends and identify recommendations to optimize safety and mobility. **Section 4.1** provides an overview of the data collection process that was used to develop the historical models for subsequent analysis. **Section 4.2** provides a summary of the data collected as a part of this process. An analysis of the traffic crash and volume data associated with the 25 freeway work zones is presented in **Section 4.3**, which was ultimately used to support the development of conclusions and recommendations presented in **Chapter 5**. **Appendix A** includes project profiles for each of the 25 freeway work zones, including a review of the safety performance along each corridor both under normal operating conditions as well as during the work period.

4.1 Data Collection

Initially, the MSU research team worked with MDOT staff to identify a total of 25 recent long-term construction projects along Michigan's freeway network for further evaluation. These sites were identified such that several projects were included from each MDOT region that incorporated a broad range of temporary traffic control configurations and roadway characteristics. It should be noted that local knowledge from MDOT staff also helped to guide this selection process towards projects that would be most suitable for study. A map of the 25 study freeway work zones that were identified via this process are shown in **Figure 34**, which represent approximately 10 percent of Michigan's freeway system.

For each of these 25 projects, a multi-stage data collection process was completed in order to develop the final study dataset, summarized in **Figure 35**. MDOT provided a series of work zone information to the MSU research team specific to each of the 25 study projects, summarized in **Table 49**. The MSU research team synthesized this information in conjunction with satellite and street view imagery in order to develop daily historical models of each work zone (summarized in **Section 4.1.1**). Next, traffic volume data (**Section 4.1.2**) and traffic crash data (**Section 4.1.3**) were added to these models for subsequent evaluation.

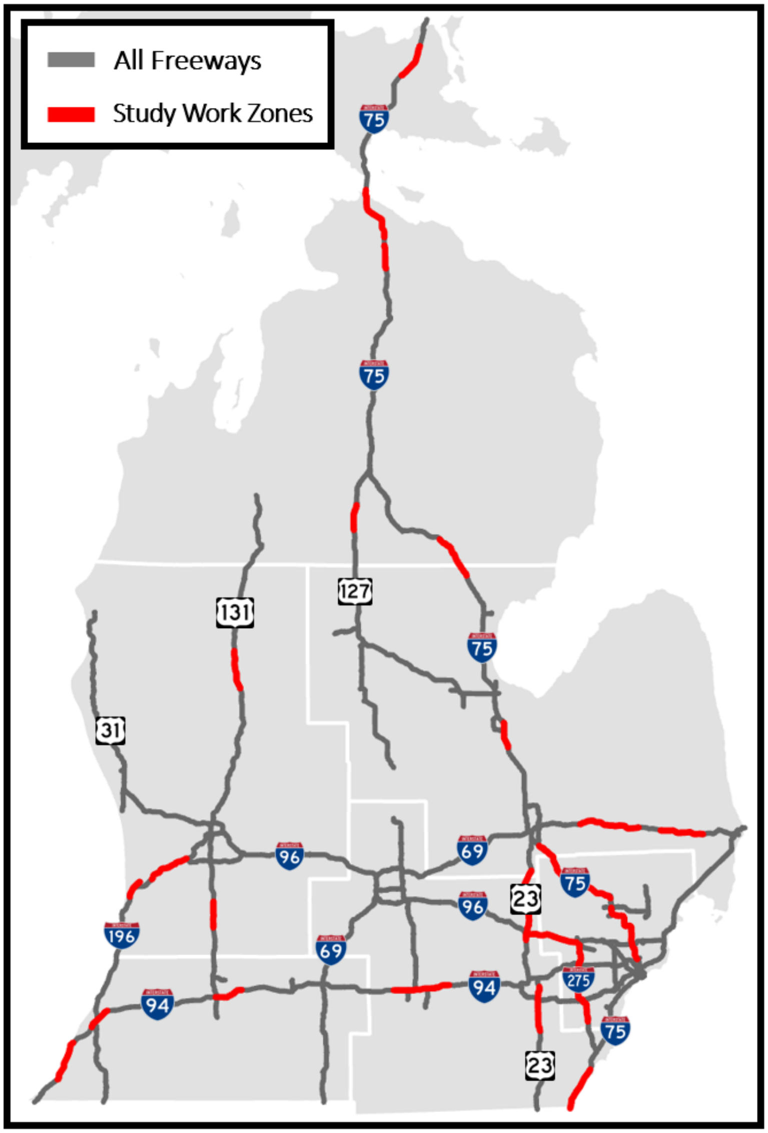


Figure 34. Map of Michigan Freeway Work Zones Evaluated in this Study (N = 25)

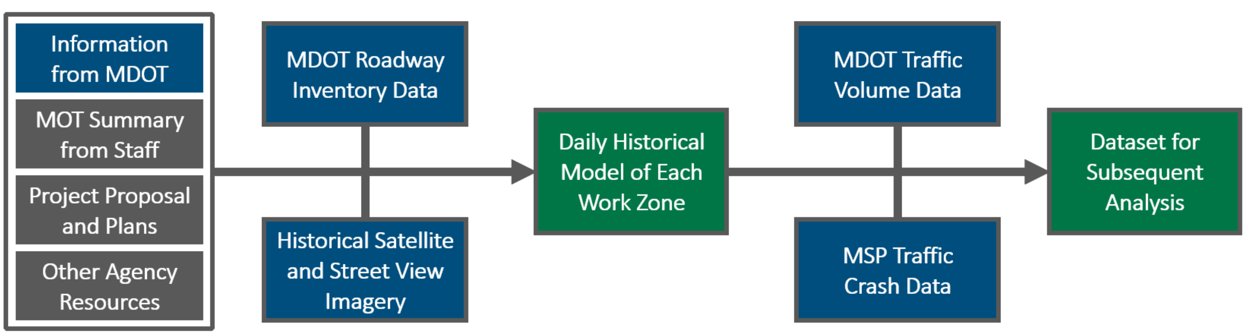


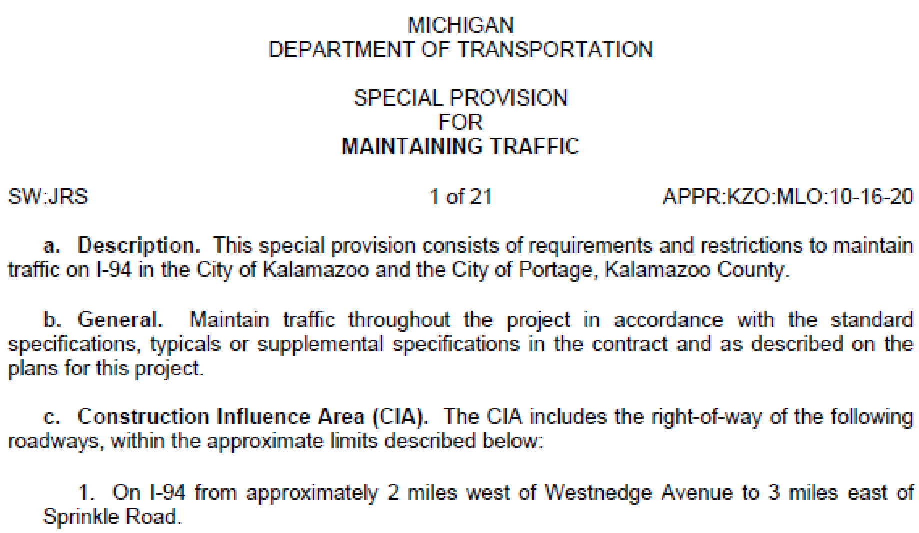
Figure 35. Overview of Data Collection Process for Each Project

Table 49. Resources Used to Obtain Information Pertaining to Each Work Zone

Resource	Description
Maintenance of Traffic Summary	MDOT staff were requested to complete a standardized summary that outlines the overall maintenance of traffic strategy that was employed for each project. This summary provided critical context from MDOT staff with direct knowledge of the project. Most importantly, the summary included a general timeline of staging and closure information for the research team (to the extent possible).
Project Proposal	While the materials within each project proposal represent the planned approach prior to beginning work and subsequent field conditions may vary, these materials included key details (such as special provisions or closure restrictions) that were used to inform the development of each model.
Project Plans	In addition to the proposal, the plans for each project were provided by MDOT staff. Specifically, the maintenance of traffic sheets within the project plans represented the primary resource to determine the position of temporary traffic control devices.
Inspector Reports or Lane Closure Data	While the maintenance of traffic summary, plans, and proposal represented the starting point for developing a model of each work zone, MDOT also maintains a range of other resources that can be used to more precisely identify the dates of specific stages or work zone conditions. This included daily inspector reports, lane closure data, or any other relevant information that was maintained for each project.

4.1.1 Development of Daily Work Zone Models

Given the information provided by MDOT in **Table 49**, historical daily work zone models were developed for each of the 25 study projects. This process typically began with the proposal with a focus on the special provision for maintaining traffic, shown in **Figure 36**. The special provision includes key details such as the construction influence area defined by MDOT, traffic restrictions, the list of maintaining traffic typicals to be used as a part of the project, staging information, and other traffic information.



MICHIGAN
DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION
FOR
MAINTAINING TRAFFIC

SW:JRS 1 of 21 APPR:KZO:MLO:10-16-20

a. Description. This special provision consists of requirements and restrictions to maintain traffic on I-94 in the City of Kalamazoo and the City of Portage, Kalamazoo County.

b. General. Maintain traffic throughout the project in accordance with the standard specifications, typicals or supplemental specifications in the contract and as described on the plans for this project.

c. Construction Influence Area (CIA). The CIA includes the right-of-way of the following roadways, within the approximate limits described below:

1. On I-94 from approximately 2 miles west of Westnedge Avenue to 3 miles east of Sprinkle Road.

Figure 36. Example MDOT Special Provision for Maintaining Traffic

Next, the maintenance of traffic sheets from the project plans (**Figure 37**) were used to identify the intended placement of traffic control devices. This information was used in conjunction with historical street view (**Figure 38**) and satellite (**Figure 39**) imagery where available to confirm the overall configuration as well as the location of specific devices.

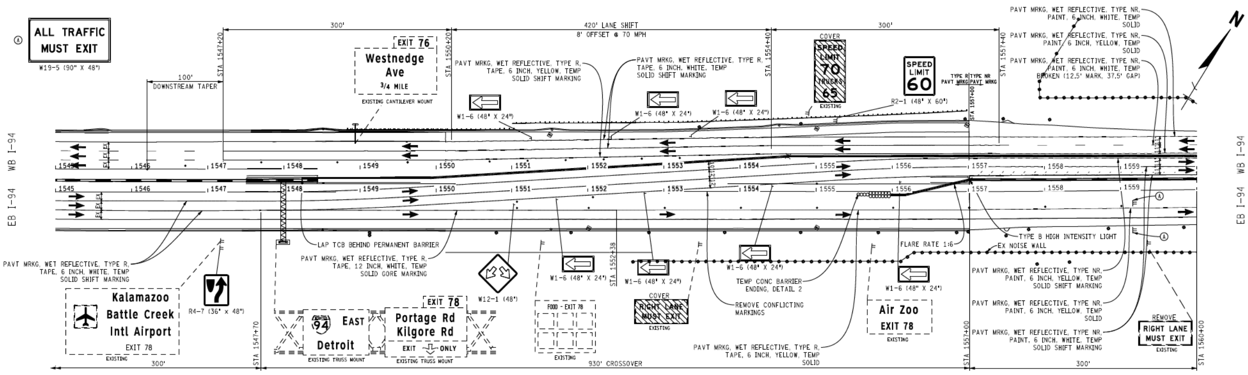


Figure 37. Example Maintenance of Traffic Plan


Figure 38. Example of Temporary Traffic Control in Historical Street View Imagery [*277*]


Figure 39. Example of Temporary Traffic Control in Historical Satellite Imagery [*277*]

Ultimately, the daily historical work zone models of each project were developed in a manner such that the data could be aggregated across projects for subsequent analysis. An example of a single stage of an example project for one direction of travel is shown in **Figure 40**. This was conducted using MDOT's *Roads & Highways Centerline Attribution Data* Version 23 [*5*] as the base roadway inventory for the project. Roadway inventory data for impacted freeway ramps within activity areas were also collected for each project (**Figure 41**). These facilities were evaluated as a part of a distinct process, where the summation of the mainline freeway segments and the freeway ramp facilities comprise the overall model of each work zone. Each work zone was disaggregated into the components of a temporary traffic control zone consistent with the MUTCD [*6*] to the extent possible, as described in **Table 50**.

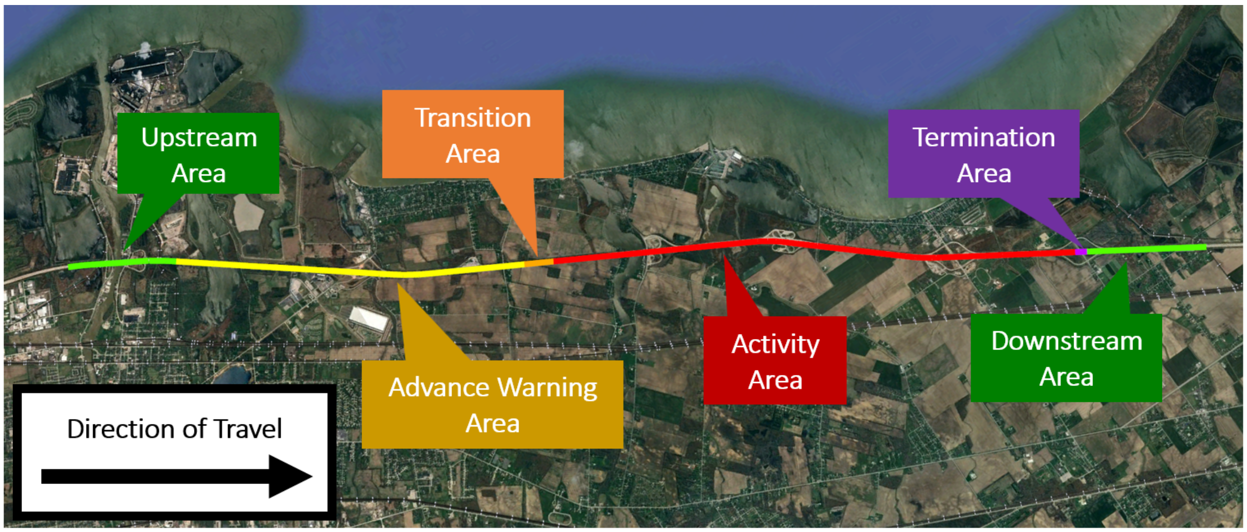


Figure 40. Example of Work Zone Model for One Direction and Stage of Freeway Project

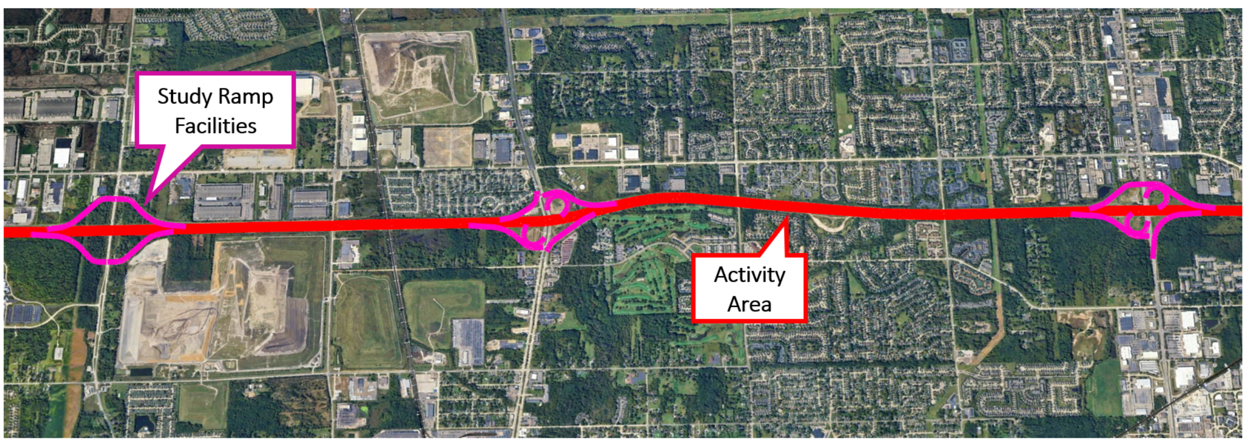


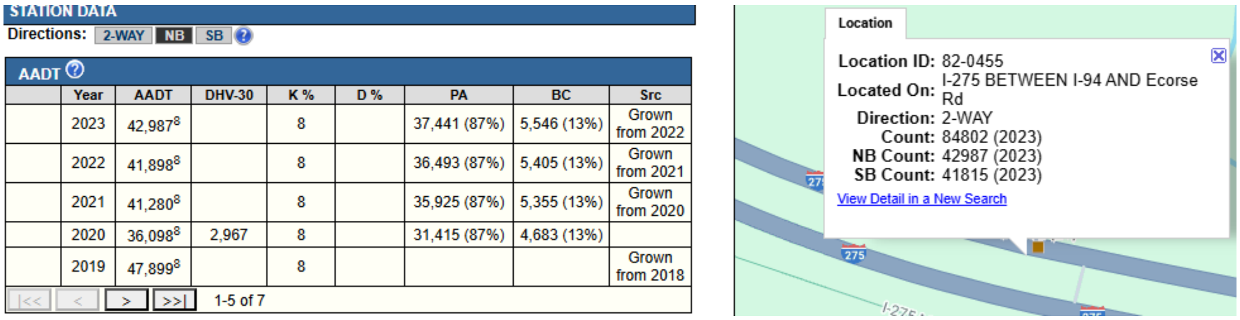
Figure 41. Example of Freeway Ramps included in Work Zone Model

Table 50. Areas of the Work Zone included in the Evaluation

Area	Description
Upstream	The area up to approximately one mile upstream of the beginning of the advance warning area was included as a part of each model to identify any upstream impacts of the work zone presence and ensure that all relevant crash records were obtained. It should be noted that the upstream area may have been truncated in cases where the route ends or major roadway characteristics are different from the work area.
Advance Warning	The area upstream of the work area where road users are informed about the upcoming transition and subsequent activity [*19*]. This was determined by identifying the location of warning signs and other traffic control devices (such as cases where a dynamic stopped traffic advisory system was employed) before the beginning of the transition area.
Transition	The area where road users are redirected out of their normal path [*19*], typically via appropriate channelizing devices and other temporary traffic control devices. The area extending from the first temporary traffic control device related to change in path to the beginning of the work area was considered as the transition area. In many scenarios, there could be multiple transition areas (such as a lane closure followed by a subsequent lane shift) within a single direction of travel. For scenarios where the precise location of the transition area could not be determined, this area was aggregated with the rest of activity area.
Activity	The area of the roadway where the work activity is taking place [*19*], typically comprised of the work space, traffic space, and buffer space. The area where a consistent traffic control configuration was in place (such as a lane closure or crossover) was considered as an activity area. For scenarios where the precise location of transition or termination areas could not be determined, they were aggregated with the activity area.
Termination	The area where road users are returned to their normal driving path [*19*]. The area extending from the end of the activity area to the last temporary traffic control device was identified as the termination area [*6*]. For scenarios where the precise location of the termination area could not be determined, this area was aggregated with the rest of the activity area.
Downstream	The area up to approximately one mile downstream of the end of the work area was included as a part of each model to identify any downstream impacts of the work zone presence and ensure that all relevant crash records were obtained. It should be noted that the downstream area may have been truncated in cases where the route ends or major roadway characteristics are different from the work zone area.

4.1.2 Traffic Volume Data

Historical traffic volume data were collected for all study segments within the 25 freeway project corridors from MDOT's *Traffic Count Data System* (TCDS) [*7*], shown in **Figure 42**. An estimate of the one-way annual average daily traffic (AADT) volume as well as the percentage of trucks was obtained from individual count station data for (1) each year of the study period (2016 - 2023) as well as (2) each stage of the work zone. These data were added to the historical daily models outlined in **Section 4.1.1** as shown in **Figure 43** (for a separate project). Care was taken to ensure that the AADT estimate included in TCDS was representative of field conditions by examining the underlying count data as well as data from adjacent stations.



STATION DATA

Directions: 2-WAY NB SB

AADT

	Year	AADT	DHV-30	K %	D %	PA	BC	Src
	2023	42,987[8]		8		37,441 (87%)	5,546 (13%)	Grown from 2022
	2022	41,898[8]		8		36,493 (87%)	5,405 (13%)	Grown from 2021
	2021	41,280[8]		8		35,925 (87%)	5,355 (13%)	Grown from 2020
	2020	36,098[8]	2,967	8		31,415 (87%)	4,683 (13%)	
	2019	47,899[8]		8				Grown from 2018

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Figure 42. Excerpt from MDOT's Traffic Count Data System [*278*]

Area	Condition	PR	BMP	EMP	Length	Lanes	Stage	Start	End	Days	AADT	VMT	Truck%
Upstream	Open	1431603	13.42	14.13	0.71	2	Stage 2b	6/19/2023	7/24/2023	36	37,751	969,631	11%
Upstream	Open	1431603	13.13	13.42	0.29	2	Stage 2b	6/19/2023	7/24/2023	36	37,751	389,405	11%
Advance Warning	Open	1431603	11.91	13.13	1.22	2	Stage 2b	6/19/2023	7/24/2023	36	37,751	1,653,686	11%
Advance Warning	Open	1431603	10.75	11.91	1.16	2	Stage 2b	6/19/2023	7/24/2023	36	40,253	1,685,591	10%
Transition	Transition to Split Merge (1+1)	1431603	10.12	10.75	0.63	2	Stage 2b	6/19/2023	7/24/2023	36	40,253	912,938	10%
Activity	Split Merge (1 Opp+1 Outside)	1431603	8.53	10.12	1.59	2	Stage 2b	6/19/2023	7/24/2023	36	35,655	2,041,139	18%
Activity	Split Merge (1 Opp+1 Outside)	1431603	5.15	8.53	3.38	2	Stage 2b	6/19/2023	7/24/2023	36	27,937	3,396,434	27%
Activity	Split Merge (1 Opp+1 Outside)	1431603	3.37	5.15	1.78	2	Stage 2b	6/19/2023	7/24/2023	36	26,980	1,731,531	27%
Termination	End of Split Merge	1431603	2.95	3.37	0.42	2	Stage 2b	6/19/2023	7/24/2023	36	26,980	407,938	27%
Downstream	Open	1431603	1.95	2.95	1.00	2	Stage 2b	6/19/2023	7/24/2023	36	26,980	971,280	27%

Figure 43. Example of Historical Work Zone Model Data

One-way AADT estimates ranged from 1,842 vehicles per day along I-75 in the Upper Peninsula to greater than 100,000 vehicles per day along I-275 in Southeast Michigan. The distribution of directional AADT estimates across all segments evaluated as a part of this freeway evaluation is shown in **Figure 44**.

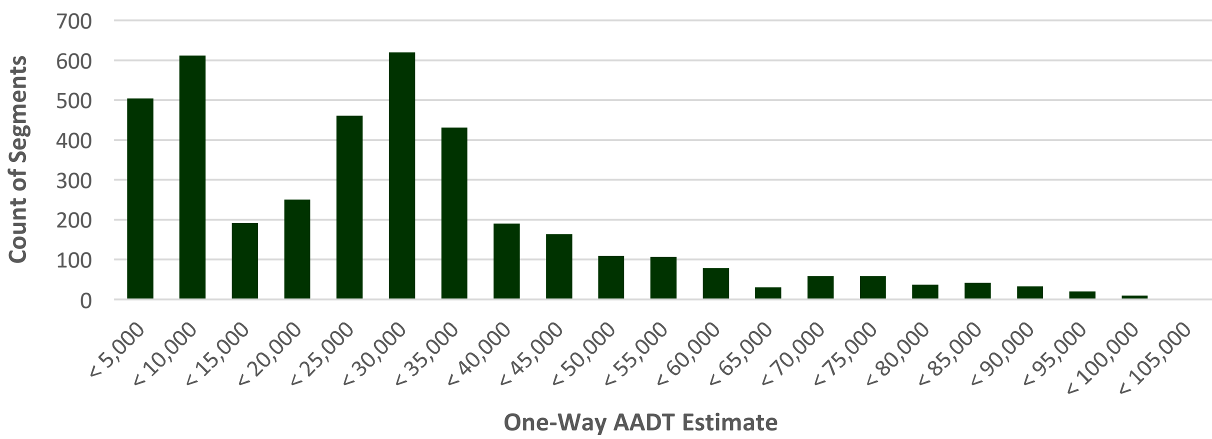


Figure 44. Distribution of Directional AADT Estimates for Study Freeway Segments

The percentage of trucks ranged from 5 percent to 42 percent with an average of 16 percent. The distribution of truck percentage across all study segments is shown in **Figure 45**.

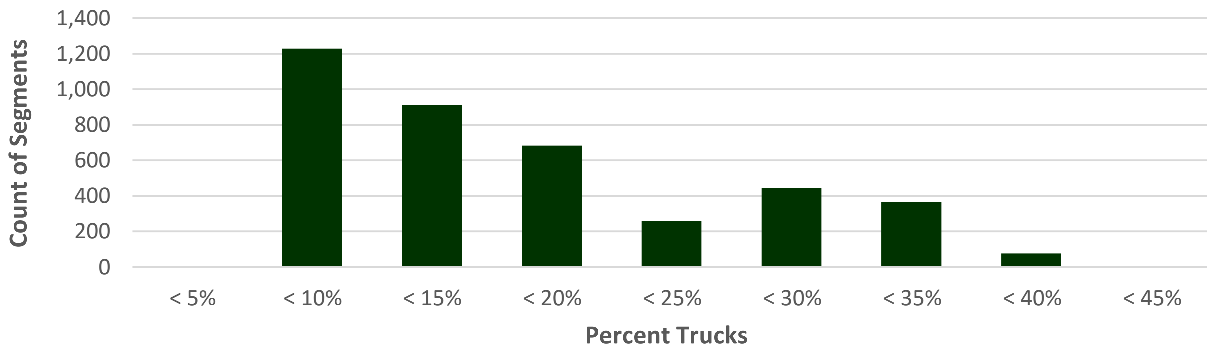


Figure 45. Distribution of Truck Percentages for Study Freeway Segments

While approximately two-thirds of exit and entrance ramps included in the study serve less than 5,000 vehicles per day, there were also select multilane facilities that exceed 60,000 vehicles per day. The distribution of one-way AADT estimates across all study exit and entrance ramps is shown in **Figure 46**.

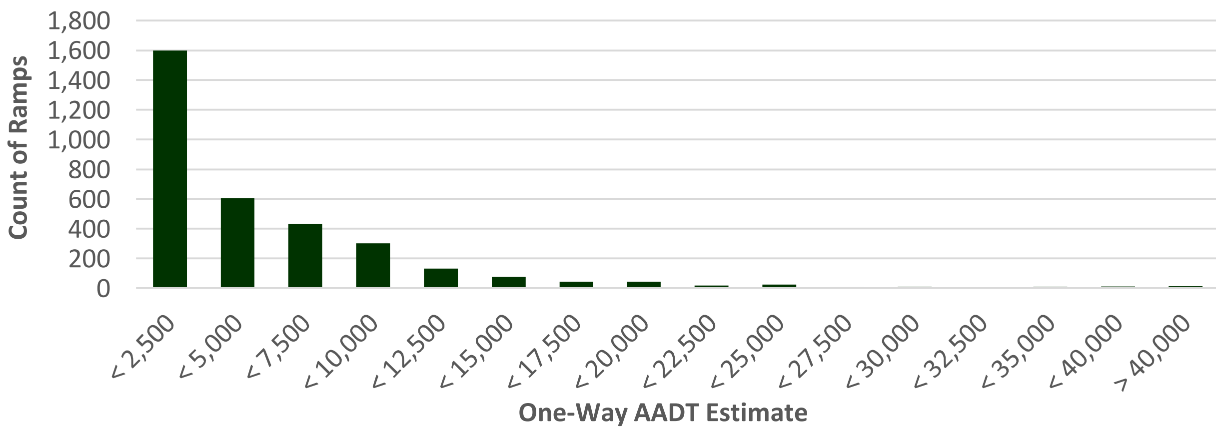


Figure 46. Distribution of AADT Estimates for Study Ramps

4.1.3 Traffic Crash Data

Historical traffic crash data were collected from the annual databases maintained by the Michigan State Police (MSP). All traffic crash records occurring within the study work zone boundaries during the eight-year study period (2016 to 2023) were collected for further screening. An example of this process along a portion of a single study work zone is shown in **Figure 47**. Next, all crash records that were coded by the responding officer as animal-related were removed from the evaluation. This process resulted in the collection of more than 50,000 total crash records occurring along the mainline freeway segments and ramp facilities during the study period.

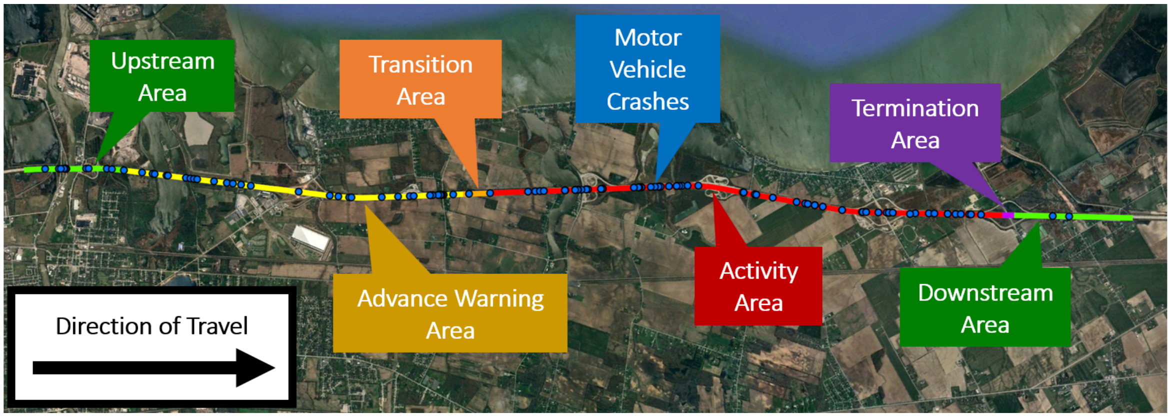


Figure 47. Example of Traffic Crash Data Collection Process

<u>4.1.3.1 Review of Michigan UD-10 Crash Report Forms</u>

In order to improve the overall accuracy of the historical traffic crash data as well as the precision of the location data associated with each record, the MSU research team reviewed the narrative and diagram (**Figure 48**) for the subset of crashes occurring within the boundaries of each work zone system within the work period and made corrections wherever necessary. A total of 8,425 crashes were reviewed as a part of this process which resulted in the correction of critical details (such as crash type or location) for 446 records to match the information in the diagram and narrative. Additionally, crashes that were erroneously located along the study route were removed from the analysis. For ramp crashes, only those crashes involving vehicles traveling along the ramp were included in the evaluation. In other words, crashes occurring within the intersection of a ramp terminal involving vehicles from adjacent surface streets (such as angle collisions involving turning vehicles) were removed from the analysis. The specific circumstances of each crash were also assessed, with a focus on the involvement of temporary traffic control, workers, work vehicles, or equipment.

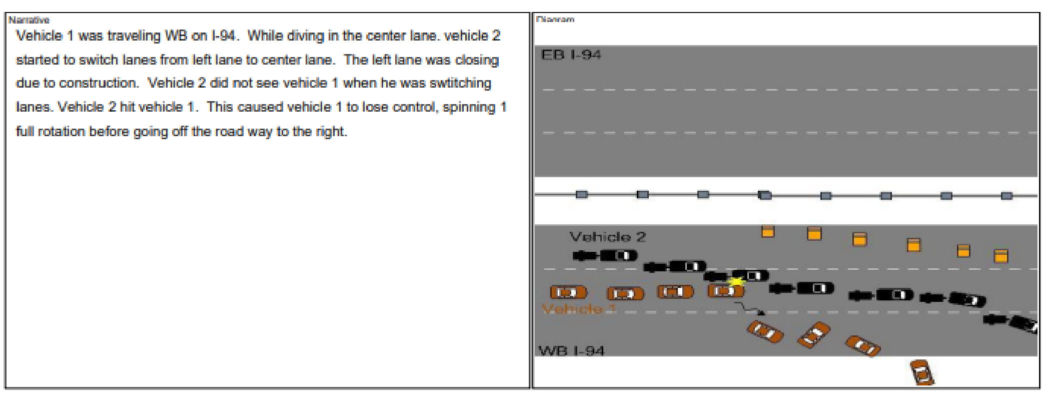


Figure 48. Example of Narrative and Diagram from UD-10 Traffic Crash Report Form

4.2 Data Summary

A final dataset that included daily work zone models of all 25 projects was developed for subsequent analysis. **Table 51** provides a summary of the primary characteristics for each project.

Table 51. Summary of Study Freeway Work Zone Projects (*N = 25*)

Project	Region	AADT	Context	Impact Area Length	Work Days	Includes Night Work	Temp. Barrier	Lane Closure	Cross-over	Split Merge	Other Project Characteristics
I-75 (8 Mile Road to South Boulevard)*	Metro	120,200	Urban	42.8	2,922	✓	✓	✓	✓		I-75 Modernization Project
I-96 (Kent Lake to I-275)*	Metro	114,900	Urban	28.6	651	✓	✓	✓	✓		I-96 Flex Route
I-275 (M-153 to 5 Mile Road)*	Metro	106,400	Urban	43.2	908	✓	✓	✓	✓		
I-75 (M-15 to Oakland County Line)*	Metro	72,826	Urban	60.5	224	✓	✓	✓	✓	✓	Stopped Traffic Advisory System
I-94 (Lovers Lane to Sprinkle Road)	Southwest	70,000	Urban	14.3	929	✓	✓	✓	✓		Widening and SPUI Conversion
US-23 (Stoney Creek Rd. to Ellsworth Rd.)*	University	66,200	Suburban	23.8	306	✓	✓	✓		✓	
I-75 (Erie Road to Otter Creek)*	University	59,200	Rural	20.0	602	✓	✓	✓	✓		
I-75 (Hess Avenue to I-675 Interchange)	Bay	56,200	Suburban	15.7	858	✓	✓	✓	✓		Moveable Barrier Wall
I-94 (Britain Avenue to I-196 Interchange)	Southwest	56,000	Suburban	12.2	577	✓	✓	✓	✓		Stopped Traffic Advisory System
US-23 (I-96 to Livingston County Line)	University	54,000	Suburban	44.8	476	✓	✓	✓	✓		Nighttime Detour
I-196 (Byron Road to 32nd Avenue)	Grand	50,000	Suburban	22.9	610	✓	✓	✓	✓		
I-94 (Blackman Road to Sargent Road)	University	48,200	Suburban	29.7	800	✓	✓	✓	✓	✓	Stopped Traffic Advisory System
I-75 (State Line to Erie Road)	University	46,900	Rural	16.6	543	✓	✓	✓	✓		Project Begins at State Line
I-94 (Red Arrow Highway to Stevensville)	Berrien	43,600	Suburban	26.1	206	✓		✓			Eastbound Only
US-131 (M-179 Interchange)	Grand	38,500	Rural	16.2	610	✓	✓	✓	✓		Includes SPUI Conversion
US-31 (I-196 NB to Central Avenue)	Grand	28,500	Suburban	10.0	218		✓	✓	✓		Northbound Closure and Detour
I-69 (M-24 to Lake George Road)	Bay	25,400	Suburban	31.5	608	✓	✓	✓	✓		
US-131 (13 Mile Road to 19 Mile Road)	Grand	19,100	Rural	23.7	111			✓			Northbound Only
I-75 (Ogemaw County Line to Cook Road)	North	15,500	Rural	23.7	220	✓	✓	✓			
I-69 (M-19 to Cox-Doty Drain)	Bay	14,600	Rural	26.8	262	✓	✓	✓	✓		
I-75 (Old M-108 to Mackinac Bridge)	North	11,400	Rural	7.8	236			✓			Full Closures
I-75 (M-27 to Topinabee Mail Route)	North	10,000	Rural	13.8	229			✓			Completed during COVID-19
I-75 (Levering Road to US-31)*	North	8,600	Rural	28.3	569		✓	✓	✓		Moveable Barrier Wall
US-127 (M-55 to Muskegon River Bridge)	North	7,780	Rural	15.2	166			✓			Double Step Down of Speed Limit
I-75 (M-80 to M-28)	Superior	6,000	Rural	20.9	166		✓	✓			
			All Projects	**619.2**	**14,007**	**18**	**20**	**25**	**17**	**3**	

Project remains ongoing beyond 2016-2023 study period

The sample of study projects includes five urban freeway projects, nine suburban freeway projects, and 11 rural freeway projects. The total impact area of all 25 projects was 619.2 miles (in both directions), ranging from 7.8 to 60.5 miles per project. A total of 14,007 work days are included in the sample, ranging from 111 to 2,922 per project. All 25 projects incorporated a lane closure, and 20 projects included the use of temporary barrier, two of which were movable barriers. A total of 18 projects included at least some work at night. Crossovers were used in 17 projects, and three projects employed a split merge. Within the sample of 25 projects, there were also three projects that included a dynamic stopped traffic advisory (e.g., queue warning) system. It is important to note that the I-75 modernization project includes work across the entire study period with complex traffic control that could not be modeled using the same approach as the other 24 projects. As a result, only a site-level analysis was included for the I-75 modernization project (which can be found in **Appendix A.25**).

4.2.1 Identification of Periods with Normal (Non-Work Zone) Operations

The construction type code associated with each crash record was used to identify periods prior to the study work zone where no construction activity was present. Years prior to the implementation of the study work zone where no significant concentrations of work zone coded crashes occurred were considered to represent "normal operations" when no temporary traffic control was present. These data can be used as a baseline to estimate safety performance for each corridor prior to the implementation of the study work zone. An example of this process for a single corridor is shown in **Figure 49,** where both the study work zone as well as a prior unrelated construction project can be seen to influence the share of work zone coded crashes.

Thus, the orange-shaded section represents the study work zone period, while the purple-shaded section represents the unrelated work zone, which was subsequently excluded from the dataset. All of the remaining periods, which are shaded in green in **Figure 49**, represented normal operations. This process was applied for all 24 study work zones that could be evaluated with this approach (or exclusive of the I-75 modernization project). Note that the periods of normal operations included work zone crashes that occurred during short term/duration maintenance or utility work. Such work was deemed normal during non-construction periods, and work zone coded crashes never amounted to more than 5 percent of total annual crashes occurring during the normal period for any of the study work zones. Full details for each project can be found in **Appendix A**.

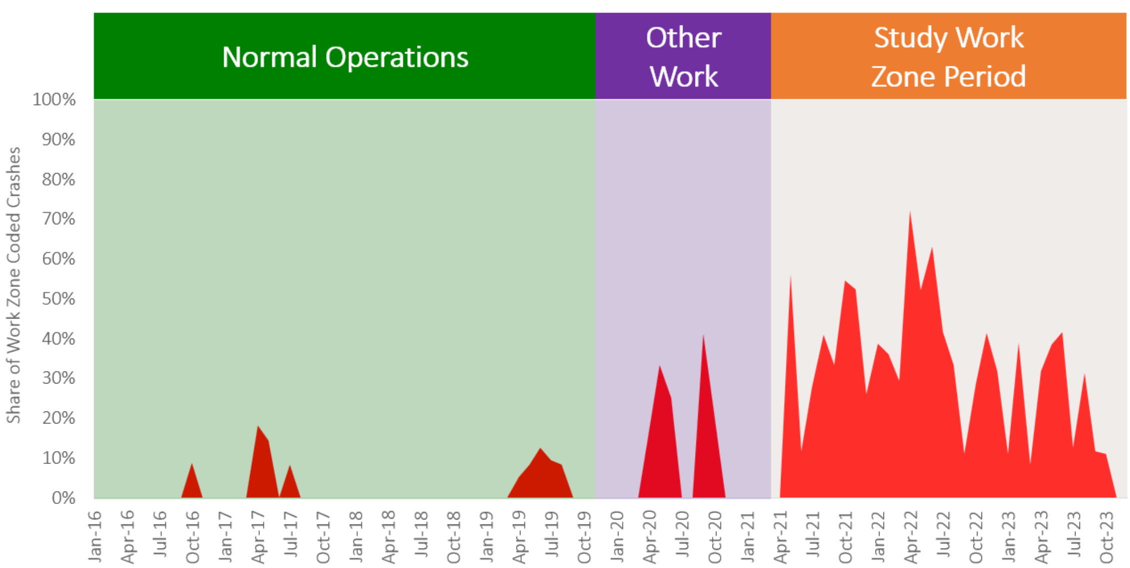


Figure 49. Work Zone Coded Crashes as a Share of Total Crashes for Example Corridor

4.2.2 Summary of Mainline Traffic Crash Data

The naïve crash rates per 100M vehicle miles traveled (VMT) for the mainline freeway segments that comprise each project are shown in **Table 52**, including crash rates both under normal operations as well as the crash rate during the study work zone period. These naïve data represent all normal operations data regardless of season as well as work zone period data (including upstream and downstream areas as well as winter shutdown periods).

Table 52. Naïve Crash Rates for All Study Work Zones (*N = 24*)

Project	Region	AADT	Context	Impact Area Length	Work Days	Naive Crash Rates						
						Normal Operations			Work Zone Operations			Percent Change
						Crashes	VMT	Rate	Crashes	VMT	Rate	
I-96 (Kent Lake to I-275)*	Metro	114,900	Urban	28.6	651	2,729	3,206,600,140	85.1	1,271	1,063,594,921	119.5	40.4%
I-275 (M-153 to 5 Mile Road)*	Metro	106,400	Urban	43.2	908	3,609	3,589,641,614	100.5	2,336	1,983,013,082	117.8	17.2%
I-75 (M-15 to Oakland County Line)*	Metro	72,826	Urban	60.5	224	2,886	3,692,615,726	78.2	402	472,118,509	85.1	8.9%
I-94 (Lovers Lane to Sprinkle Road)	Southwest	70,000	Urban	14.3	929	762	762,091,455	100.0	480	481,223,449	99.7	-0.2%
US-23 (Stoney Creek Road to Ellsworth Road)*	University	66,200	Suburban	23.8	306	1,187	1,712,838,535	69.3	249	230,397,932	108.1	56.0%
I-75 (Erie Road to Otter Creek)*	University	59,200	Rural	20.0	602	418	631,641,884	66.2	315	356,857,471	88.3	33.4%
I-75 (Hess Avenue to I-675 Interchange)	Bay	56,200	Suburban	15.7	858	348	515,227,543	67.5	324	377,175,369	85.9	27.2%
I-94 (Britain Avenue to I-196 Interchange)	Southwest	56,000	Suburban	12.2	577	374	468,782,085	79.8	179	197,069,515	90.8	13.8%
US-23 (I-96 to Livingston County Line)	University	54,000	Suburban	44.8	476	1,897	1,898,963,275	99.9	564	585,796,072	96.3	-3.6%
I-196 (Byron Road to 32nd Avenue)	Grand	50,000	Suburban	22.9	610	396	596,488,475	66.4	230	350,148,379	65.7	-1.1%
I-94 (Blackman Road to Sargent Road)	University	48,200	Suburban	29.7	800	537	533,246,372	100.7	599	563,422,418	106.3	5.6%
I-75 (State Line to Erie Road)	University	46,900	Rural	16.6	543	347	532,251,592	65.2	260	212,094,976	122.6	88.0%
I-94 (Red Arrow Highway to Stevensville)	Berrien	43,600	Suburban	26.0	206	733	1,066,950,043	68.7	68	117,284,612	58.0	-15.6%
US-131 (M-179 Interchange)	Grand	38,500	Rural	16.2	610	364	472,814,526	77.0	150	189,770,236	79.0	2.7%
US-31 (I-196 NB to Central Avenue)	Grand	28,500	Suburban	10.0	218	102	188,457,764	54.1	10	23,442,929	42.7	-21.2%
I-69 (M-24 to Lake George Road)	Bay	25,400	Suburban	22.1	608	242	629,703,018	38.4	93	233,723,854	39.8	3.5%
US-131 (13 Mile Road to 19 Mile Road)	Grand	19,100	Rural	23.7	111	149	322,996,467	46.1	13	24,834,689	52.3	13.5%
I-75 (Ogemaw County Line to Cook Road)	North	15,500	Rural	23.7	220	178	316,396,182	56.3	24	37,901,809	63.3	12.6%
I-69 (M-19 to Cox-Doty Drain)	Bay	14,600	Rural	26.8	262	92	345,039,698	26.7	18	56,125,083	32.1	20.3%
I-75 (Old M-108 to Mackinac Bridge)	North	11,400	Rural	7.8	236	35	80,666,259	43.4	12	11,536,188	104.0	139.7%
I-75 (M-27 to Topinabee Mail Route)	North	10,000	Rural	13.8	229	56	128,627,181	43.5	7	17,742,306	39.5	-9.4%
I-75 (Levering Road to US-31)*	North	8,600	Rural	28.3	569	83	271,132,472	30.6	37	73,577,923	50.3	64.3%
US-127 (M-55 to Muskegon River Bridge)	North	7,780	Rural	15.2	166	23	48,958,418	47.0	9	10,182,666	88.4	88.1%
I-75 (M-80 to M-28)	Superior	6,000	Rural	20.9	166	67	88,393,131	75.8	7	10,146,085	69.0	-9.0%
All Projects (Excluding I-75 Modernization Project)						**17,614**	**22,100,523,856**	**79.7**	**7,657**	**7,679,180,475**	**99.7**	**25.1%**

***Project remains ongoing beyond 2016-2023 study period**

Crash rates under normal operations ranged from 26.7 to in a rural setting to more than 100.0 along high volume suburban and urban freeways, where the average crash rate across all projects was 79.7. Crash rates while a work zone was in place ranged from 32.1 to 122.6, where the average crash rate increased to 99.7. As shown in **Table 53**, there were four general categories of freeway scenarios under normal operations that influence crash rates.

Table 53. Naïve Crash Rates by Normal Operations Category

Category	Projects	Min AADT	Max AADT	Impact Area Length	Naive Crash Rates						
					Normal Operations			Work Zone Operations			Percent Change
					Crashes	VMT	Rate	Crashes	VMT	Rate	
Urban Freeway Reconstruction Projects with Major Volume Impacts	2	106,400	114,900	71.8	6,338	6,796,241,754	93.3	3,607	3,046,608,004	118.4	27.0%
High AADT Suburban and Urban Freeways with Regular Recurring Congestion	5	48,200	72,826	161.6	6,456	7,355,698,913	87.8	2,224	2,299,629,963	96.7	10.2%
Moderate AADT Rural and Suburban Freeways with Low Recurring Congestion	9	25,400	66,200	173.4	4,137	6,346,373,381	65.2	1,699	2,090,895,759	81.3	24.7%
Low AADT Rural Freeways with Rare Congestion	8	6,000	19,100	160.2	683	1,602,209,809	42.6	127	242,046,749	52.5	23.1%
All Sites (*Excluding I-75 Modernization Project*)	**24**	**6,000**	**114,900**	**566.8**	**17,614**	**22,100,523,856**	**79.7**	**7,657**	**7,679,180,475**	**99.7**	**25.1%**

First, seven projects included work zones implemented along urban and suburban freeway facilities that regularly experience recurring congestion under normal operations. These projects tended to experience considerably higher crash rates under normal conditions compared to the remaining 17 projects along suburban and rural freeway facilities that do not experience such regular daily recurring congestion. This is primarily driven by higher rates of rear end collisions related to unstable flow conditions that are present on a typical day with no work zone.

Two of these seven projects (along I-96 and I-275) where traffic volumes exceed 100,000 vehicles per day under normal conditions experienced considerable reductions in capacity during the work period. Therefore, these two work zones represent a distinctly different analysis scenario than the other five projects with regular recurring congestion (where there were generally less dramatic impacts to capacity). This can be observed from **Table 53**, where the two high volume projects experienced a larger relative increase in naïve crash rate (27.0 percent) than did the remaining five (10.2 percent). It is important to recognize that this group of five projects tended to experience a lower relative increase in naïve crash rates compared to the other study projects.

The nine rural and suburban freeway projects that serve moderate traffic volumes but do not regularly observe recurring congestion under normal operations experienced an increase in naïve crash rate of 24.7 percent. This is primarily driven by an increase in rear end collisions related to the additional periods of unstable flow that is induced along these corridors due to the presence of the work zone. Similarly, rural freeway facilities where congestion is rare under normal operations experienced a 23.1 percent increase in naïve crash rate. Three of the four largest relative increases in crash rates occurred along these low-volume rural facilities.

The frequency of crashes and average crash rates for all segments in the evaluation are summarized by condition and work area in **Table 54**. The naïve data represents all data from the eight-year study period regardless of work zone condition. The normal operations data represents all periods in the evaluation where no construction activity was occurring. Aggregate crash rates when a work zone is in place are also shown by work area consistent with the definitions presented in **Table 50**. Aggregate crash rates for the winter shutdown periods are also provided in **Table 54**. Frequencies and rates are provided for all crashes, fatal and injury (FI) crashes, as well as crashes coded by the responding officer as occurring in a work zone.

Table 54. Average Crash Rates by Area within the Work Zone

Condition or Area	VMT	Crashes		Work Zone Coded		Crash Rate		
		Total	FI	Count	Share	Total	FI	WZ Coded
Naïve (All Data)	40,966,692,573	33,006	5,933	5,061	15.3%	80.6	14.5	12.4
Normal Operations	22,100,523,856	17,614	3,204	360	2.0%	79.7	14.5	1.6
Upstream	511,951,147	404	72	71	17.6%	78.9	14.1	13.9
Advance Warning	844,939,612	753	140	103	13.7%	89.1	16.6	12.2
Transition	52,125,593	73	14	46	63.0%	140.0	26.9	88.2
Activity	4,548,727,034	5,090	854	3,332	65.5%	111.9	18.8	73.3
Termination	63,080,717	46	4	23	50.0%	72.9	6.3	36.5
Downstream	657,876,099	477	79	86	18.0%	72.5	12.0	13.1
Winter Shutdown	1,000,480,272	814	135	46	5.7%	81.4	13.5	4.6
All Work Areas	**7,679,180,475**	**7,657**	**1,298**	**3,707**	**48.4%**	**99.7**	**16.9**	**48.3**

While the aggregate crash rates for the naïve and normal operations periods are relatively similar, it can be observed from **Table 54** that the normal operations data includes only a limited number of work zone-coded crashes (2.0 percent) compared to all periods in the study (15.3%). Crash rates were considerably higher during the work period, where the highest rates are observed within transition areas (140.0), activity areas (111.9), and advance warning areas (89.1). A similar pattern can also be observed for fatal and injury crash (FI) rates.

Table 54 also demonstrates that crashes occurring within work zones are often not being coded as such by the responding officer. This could lead to a potential underreporting of crashes if an analyst used the work zone fields alone to conduct a safety performance evaluation. Additionally, this limits the effectiveness of the new fields that were added to the UD-10 report associated with work zones in 2016. Further, a total of 322 crashes (or greater than 4%) reviewed as a part of this study included references to the presence of a work zone in the crash report narrative and diagram but were not coded as occurring within a work zone. Most collisions within advance warning areas (13.6 percent) are not being coded as occurring within a work zone. While these rates were intuitively the highest within transition and activity areas, underreporting remains a considerable concern.

The frequency and average crash rates for all study segments by worst injury in the crash are provided in **Table 55**. A total of 22 fatal (K) crashes and 98 serious (A) injury crashes occurred during the work periods along study segments. While the sample size of data specific to transition areas is too small to detect a statistically significant change in crash severity, **Table 55** provides evidence that the rates of injury crashes tended to be considerably higher in transition areas than other areas of the work zone or safety performance under normal operations.

Table 55. Average Crash Rates by Worst Injury and Area within the Work Zone

Condition or Area	VMT	Crashes					Crash Rate				
		K	A	B	C	PDO	K	A	B	C	PDO
Naïve (All Data)	40,966,692,573	125	471	1,618	3,719	27,073	0.3	1.1	3.9	9.1	66.1
Normal Operations	22,100,523,856	57	246	842	2,059	14,410	0.3	1.1	3.8	9.3	65.2
Upstream	511,951,147	2	10	18	42	332	0.4	2.0	3.5	8.2	64.8
Advance Warning	844,939,612	3	14	35	88	613	0.4	1.7	4.1	10.4	72.5
Transition	52,125,593	0	4	3	7	59	0.0	7.7	5.8	13.4	113.2
Activity	4,548,727,034	11	63	217	563	4236	0.2	1.4	4.8	12.4	93.1
Termination	63,080,717	0	0	1	3	42	0.0	0.0	1.6	4.8	66.6
Downstream	657,876,099	3	0	35	41	398	0.5	0.0	5.3	6.2	60.5
Winter Shutdown	1,000,480,272	3	7	47	78	679	0.3	0.7	4.7	7.8	67.9
All Work Areas	**7,679,180,475**	**22**	**98**	**356**	**822**	**6,359**	**0.3**	**1.3**	**4.6**	**10.7**	**82.8**

The frequency and average crash rates for all study segments by crash type are provided in **Table 56**. It should be noted that the crash data specific to the work zone period has been modified as a part of the manual review of crashes outlined in **Section 4.1.3.1**. As such, **Table 56** should be interpreted with caution due to the fact that many of the head on and angle collisions occurring in the normal operations period (which were not reviewed) are likely miscoded.

Table 56. Average Crash Rates by Type and Area within the Work Zone

Condition or Area	VMT	Crashes							Crash Rate						
		Single Vehicle	Head On	Angle	Rear End	Side-swipe Same	Side-swipe Opp.	Other	Single Vehicle	Head On	Angle	Rear End	Side-swipe Same	Side-swipe Opp.	Other
Naïve (All Data)	40,966,692,573	12,621	70	151	10,977	7,257	38	1,892	30.8	0.2	0.4	26.8	17.7	0.1	4.6
Normal	22,100,523,856	6,693	40	117	6,054	3,624	24	1,062	30.3	0.2	0.5	27.4	16.4	0.1	4.8
Upstream	511,951,147	107	0	0	172	100	1	24	20.9	0.0	0.0	33.6	19.5	0.2	4.7
Advance Warning	844,939,612	195	0	0	344	179	1	34	23.1	0.0	0.0	40.7	21.2	0.1	4.0
Transition	52,125,593	23	0	0	19	30	0	1	44.1	0.0	0.0	36.5	57.6	0.0	1.9
Activity	4,548,727,034	1,290	6	1	2,263	1,332	1	197	28.4	0.1	0.0	49.8	29.3	0.0	4.3
Termination	63,080,717	17	0	0	12	16	0	1	26.9	0.0	0.0	19.0	25.4	0.0	1.6
Downstream	657,876,099	174	1	2	135	139	0	26	26.4	0.2	0.3	20.5	21.1	0.0	4.0
Winter Shutdown	1,000,480,272	415	1	0	153	199	0	46	41.5	0.1	0.0	15.3	19.9	0.0	4.6
All Work Areas	**7,679,180,475**	**2,221**	**8**	**3**	**3,098**	**1,995**	**3**	**329**	**28.9**	**0.1**	**0.0**	**40.3**	**26.0**	**0.0**	**4.3**

The elevated rate of single vehicle and sideswipe same crashes occurring with transition areas were primarily driven by drivers failing to negotiate the temporary traffic control, resulting in either collisions with other motor vehicles or striking temporary traffic control devices. The rate of rear end collisions also was considerably larger than under normal operations as vehicles enter the upstream area and into the activity area. Rates of rear end collisions were highest within the activity areas (as opposed to in advance of the work zone).

Ultimately, concentrations of rear end collisions related to vehicles stopping or slowing within the work zone tended to occur wherever triggers for unstable flow may be present. While work zone temporary traffic control (in particular lane closures) represent one such potential trigger, a number of unrelated roadway features can also contribute to these unstable flow conditions. For example, portions of activity areas within the middle of a work zone adjacent to ramp facilities or horizontal curvature that do not commonly experience recurring congestion under normal conditions may suddenly experience unstable flow conditions during a typical work day due to the added presence of temporary traffic control.

It is also important to recognize that the rate of single vehicle collisions is considerably higher during the winter shutdown period. This emphasizes the importance of considering how winter-season conditions vary versus the typical construction period when identifying a baseline of safety performance under normal conditions.

A summary of crashes occurring at night (between 9 P.M. to 6. A.M.), crashes involving trucks, and crashes where workers were present for all study segments is provided in **Table 57**. The percentage of crashes occurring at night is generally similar between normal operations and work periods. The share of truck-involved crashes was considerably higher within transition, activity, and termination areas compared to other work areas or normal conditions. Workers were present in approximately 13 percent of all crashes occurring within the study work zone areas, where the highest share is observed within activity areas (17.5 percent).

Table 57. Nighttime, Truck-Involved and Worker Present Crashes by Area in Work Zone

Condition or Area	VMT	Crashes			Percent of All Crashes		
		Night (9 PM - 6 AM)	Truck-Involved	Worker Presence	Night (9 PM - 6 AM)	Truck-Involved	Worker Present
Naïve (All Data)	40,966,692,573	5,639	4,722	1,362	17.1%	14.3%	4.1%
Normal Operations	22,100,523,856	2,935	2,125	141	16.7%	12.1%	0.8%
Upstream	511,951,147	70	61	17	17.3%	15.1%	4.2%
Advance Warning	844,939,612	103	113	18	13.7%	15.0%	2.4%
Transition	52,125,593	12	23	8	16.4%	31.5%	11.0%
Activity	4,548,727,034	827	984	897	16.2%	19.3%	17.6%
Termination	63,080,717	9	13	8	19.6%	28.3%	17.4%
Downstream	657,876,099	75	66	12	15.7%	13.8%	2.5%
Winter Shutdown	1,000,480,272	164	121	12	20.1%	14.9%	1.5%
All Work Areas	**7,679,180,475**	**1,260**	**1,381**	**972**	**16.5%**	**18.0%**	**12.7%**

With respect to the construction location field included within the updated UD-10 crash report form, **Table 58** provides a summary of the share of all crashes coded by the officer in each work zone location category by condition or work area. "Between the First and Last Work Zone Warning Sign" is the most commonly selected value regardless of the position in the work zone.

Table 58. Summary of Construction Location Field by Area within the Work Zone

Condition or Area	Percent of All Crashes		
	Before the First Warning Sign	Between First and Last Warning Sign	No Warning Signs
Naïve (All Data)	0.6%	14.3%	0.2%
Normal Operations	0.2%	1.5%	0.1%
Upstream	1.7%	15.8%	0.0%
Advance Warning	2.9%	10.8%	0.0%
Transition	8.2%	53.4%	1.4%
Activity	1.4%	63.5%	0.6%
Termination	2.2%	47.8%	0.0%
Downstream	0.4%	16.6%	1.0%
Winter Shutdown	0.4%	5.0%	0.2%
All Work Areas	**1.5%**	**46.5%**	**0.5%**

The frequency of crashes and average crash rates within transition areas are summarized by temporary traffic control configuration in **Table 59**. It should be noted that **Table 59** aggregates 12 total transition area types in the study into five distinct categories. While the sample sizes are likely too small to determine any statistically significant differences in safety performance across types, it can be observed from **Table 59** that crash rates were highest for transitions to a split merge configuration. Regardless of the type of transition, average crash rates were higher compared to the safety performance observed under normal conditions.

Table 59. Average Work Zone Crash Rates within Transition Areas by TTC Configuration

Temporary Traffic Control Configuration	VMT	Crashes		Work Zone Coded		Crash Rate		
		Total	FI	Count	Share	Total	FI	WZ Coded
Closure of Shoulders	2,253,067	2	1	1	50%	88.8	44.4	44.4
Lane Shifts	11,827,109	15	3	10	67%	126.8	25.4	84.6
Lane Closures	20,886,366	31	7	18	58%	148.4	33.5	86.2
Vehicles Crossed Over	13,311,336	18	2	11	61%	135.2	15.0	82.6
Transition to Split Merge	3,847,715	7	1	6	86%	181.9	26.0	155.9
All Transition Areas	**52,125,593**	**73**	**14**	**46**	**63%**	**140.0**	**26.9**	**88.2**

The frequency of crashes and crash rates by the type of activity area are summarized in **Table 60**. It should be noted that **Table 60** aggregates a broad range of 31 total temporary traffic control configurations included in the study into seven distinct categories. In other words, left and right lane closures have been aggregated into a single category in **Table 60**. Additionally, the reconstruction work with unknown temporary traffic control category is comprised of three high volume urban projects completed primarily via lane closures and crossovers, but the details of the temporary traffic control within the activity area could not be determined.

Table 60. Average Crash Rates by TTC Configuration within Activity Area

Temporary Traffic Control Configuration	VMT	Crashes		Work Zone Coded		Crash Rate		
		Total	FI	Count	Share	Total	FI	WZ Coded
Shoulder Closures or Pre-Work with Limited TTC	313,158,774	161	23	14	9%	51.4	7.3	4.5
Lane Shifts	46,985,834	58	8	37	64%	123.4	17.0	78.7
Intermittent Lane Closures	665,673,084	543	98	202	37%	81.6	14.7	30.3
Lane Closures	230,497,841	218	39	166	76%	94.6	16.9	72.0
Crossovers	609,018,274	582	96	435	75%	95.6	15.8	71.4
Split Merges	36,768,941	36	7	32	89%	97.9	19.0	87.0
Reconstruction Work with Unknown TTC	2,646,624,286	3,491	583	2,446	70%	131.9	22.0	92.4
All Activity Areas	**4,548,727,034**	**5,089**	**854**	**3,332**	**65%**	**111.9**	**18.8**	**73.3**

Aside from scenarios where tree clearing, shoulder closures, pre-work, or other minor activities are ongoing, aggregate crash rates within activity areas are consistently larger compared to the safety performance observed under normal conditions. Intuitively, both the share of work zone coded crashes and the average crash rate tended to be lower for intermittent lane closures compared to the other major work types. Excluding intermittent lane closures, the share of crashes coded as occurring within a work zone by the responding officer ranged from 64 to 89 percent for the major work types. **Table 61** provides a summary of the share of each of the construction activity categories included in the revised UD-10 form out of all crashes occurring with activity areas. In general, the construction activity field does a relatively poor job identifying the actual work activity during the time of the crash.

Table 61. Share of Crashes by TTC Configuration and UD-10 Construction Activity Code

Temporary Traffic Control Configuration	VMT	Share of All Crashes				
		Lane Closure	Lane Shift or Crossover	Shoulder or Median Work	Intermittent or Moving Work	Other
Shoulder Closures or Pre-Work with Limited TTC	313,158,774	5.0%	0.6%	2.5%	0.6%	0.0%
Lane Shifts	46,985,834	10.3%	10.3%	15.5%	0.0%	27.6%
Intermittent Lane Closures	665,673,084	21.0%	6.4%	6.8%	0.7%	2.2%
Lane Closures	230,497,841	59.2%	10.1%	5.0%	0.5%	1.4%
Crossovers	609,018,274	32.6%	24.2%	10.5%	0.9%	6.5%
Split Merges	36,768,941	27.8%	41.7%	11.1%	2.8%	5.6%
Reconstruction Work with Unknown TTC	2,646,624,286	37.5%	15.8%	9.6%	1.5%	5.6%
All Activity Areas	**4,548,727,034**	**34.7%**	**15.2%**	**9.0%**	**1.3%**	**5.3%**

As a part of reviewing the narrative and diagram included with each traffic crash report form as outlined in **Section 4.1.3.1**, the specific circumstances of each crash occurring within each study work zone were assessed with a focus on the involvement of temporary traffic control, workers, work vehicles, or equipment. These findings are summarized in **Table 62,** where common work zone crash scenarios (such as strikes of channelizing devices or rear end collisions related to vehicles stopping or slowing within the work zone) are highlighted.

It is important to recognize that due to the inconsistent and incomplete nature of potentially important details that are recorded in the crash report narratives and diagrams, it is not always possible to identify the underlying circumstance. Therefore, the findings presented in **Table 62** should be interpreted with caution and are used only to provide context towards translating the information contained in the narrative and diagram of these crashes.

Table 62. Summary of Circumstances for Traffic Crashes occurring in Study Work Zones

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	52	0.6%
	Vehicle(s) Struck Channelizing Devices	127	1.5%
	Sideswipe Same Collisions Related to Lane Closure	73	0.9%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	1,893	22.5%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	118	1.4%
	Vehicle(s) Entered Work Area	17	0.2%
	Collisions involving Work Vehicles	36	0.4%
	Collisions involving Workers	3	0.0%
	Other Work Zone Related Motor Vehicle Crashes	176	2.1%
	All Common Work Zone Crash Scenarios	**2,495**	**29.6%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	1,759	20.9%
	Other Sideswipe Same Collisions	1,814	21.5%
	Other Rear End Collisions	1,297	15.4%
	Rear End Collisions at Ramp Termini	263	3.1%
	Vehicles Striking Loose Objects on Roadway	297	3.5%
	Vehicles Struck Pedestrian on Freeway	5	0.1%
	Vehicles Struck Pedestrian at Ramp Termini	4	0.0%
	Vehicles Struck Bicyclist at Ramp Termini	5	0.1%
	Other Motor Vehicle Crashes	486	5.8%
	All Other Motor Vehicle Crashes	**5,930**	**70.4%**
	Total	**8,425**	**100.0%**

While reported strikes of channelizing devices or other temporary traffic control devices are relatively rare (or approximately 2.1 percent of all work zone crashes), these incidents are consistently occurring across all roadway contexts and work areas. The sample of sideswipe same collisions related to a lane closure (73 crashes) and rear end collisions related to vehicles stopping or slowing in the work zone (1,893) represent common freeway work zone crash scenarios of concern. Fortunately, crashes where vehicles either struck workers (3) or otherwise entered a protected workspace (17) were relatively rare.

4.2.3 Summary of Freeway Ramp Traffic Crash Data

A summary of the crash data associated with the freeway ramps evaluated in the study is provided in **Table 63**. This includes all motor vehicle crashes occurring along these facilities consistent with the process shown in **Figure 47**, as well as the subset of the collisions identified by the responding officer as occurring within a work zone. Findings are presented for all data included in the study regardless of work activity, data for periods under normal operations (when no work activity was present), and for three distinct work conditions (which were partial closures or local exits, intermittent closures, and periods where the ramps were generally open to traffic).

Table 63. Summary of Freeway Ramp Crash Data

Ramp Information			Crashes			Crashes per Day	
Condition	Days	VMT	Total	WZ Coded	Share	Total	WZ Coded
Naïve (*All Data*)	864,912	1,358,763,231	4,570	217	4.7%	0.0053	0.0003
Normal Operations (*No Work Zones*)	420,714	688,610,565	2,562	18	0.7%	0.0061	0.0000
Partial Closures or Local Exits	806	321,112	5	1	20.0%	0.0062	0.0012
Intermittent Closures	14,649	8,978,688	60	10	16.7%	0.0041	0.0007
Generally Open to Traffic	145,023	306,471,255	700	141	20.1%	0.0048	0.0010

Under normal operations, the ramp facilities evaluated in the study experience approximately 0.0061 motor vehicle crashes per day. The ramp facilities where active work was ongoing on aggregate tended to experience fewer motor vehicle crashes per day than the same ramps under normal operations. However, this finding should be interpreted with caution due to the fact that there were likely days (or portions of days) in the sample where ramp facilities were closed and the closure was not identified as part of the data collection process.

Findings are also presented in **Table 64** from the review of UD-10 crash report forms outlined in **Section 4.1.3.1** for the subset of crashes occurring along freeway ramps during active work periods. The majority of these crash report forms (88.5 percent) do not identify any relationship between the circumstances of the work zone temporary traffic control, where the most common circumstance (34.2 percent) involved rear end collisions at the ramp termini that were generally unrelated to the work zone. On the aggregate, freeway ramp safety performance does not appear to be considerably degraded as a part of these construction efforts. This is also consistent with the project-level analysis provided within **Appendix A**, where there are only rare instances of ramps experiencing concentrations of collisions related to temporary traffic control.

Table 64. Summary of Circumstances for Work Zone Traffic Crashes occurring along Ramps

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	6	0.8%
	Vehicle(s) Struck Channelizing Devices	14	1.8%
	Sideswipe Same Collisions Related to Lane Closure	1	0.1%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	41	5.3%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	1	0.1%
	Vehicle(s) Entered Work Area	2	0.3%
	Collisions involving Work Vehicles	5	0.7%
	Collisions involving Workers	1	0.1%
	Other Work Zone Related Motor Vehicle Crashes	17	2.2%
	All Motor Vehicle Crashes Directly Related to Work Zone	**88**	**11.5%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	163	21.2%
	Other Sideswipe Same Collisions	107	13.9%
	Other Rear End Collisions	95	12.4%
	Rear End Collisions at Ramp Termini	263	34.2%
	Vehicles Striking Loose Objects on Roadway	4	0.5%
	Vehicles Struck Pedestrian at Ramp Termini	4	0.5%
	Vehicles Struck Bicyclist at Ramp Termini	5	0.7%
	Other Motor Vehicle Crashes	39	5.1%
	All Other Motor Vehicle Crashes	**680**	**88.5%**
	Total	**768**	**100.0%**

4.3 Data Analysis

The safety performance impacts associated with the 24 freeway construction projects (exclusive of the I-75 modernization project) were assessed to quantify the potential trends summarized in **Section 4.2**. This analysis was conducted consistent with the literature outlined in **Section 2.1.1**, including the Empirical Bayes (EB) method outlined in AASHTO's *Highway Safety Manual* [*14*]. This process considered important differences between construction-season (which typically occurs during warmer months) and winter-season safety performance observed along freeways in Michigan, outlined in **Section 4.3.1**. Ultimately, the findings of this analysis were used to support the development of recommendations and associated safety tools for MDOT presented in **Chapter 5**.

4.3.1 Construction-Season versus Winter-Season Safety Performance

A critical consideration as a part of evaluating safety performance along highway work zones in Michigan involves the potential differences observed during the construction-season (where snowy or icy pavement conditions are relatively rare) and the winter-season (where such pavement conditions are relatively common). As shown in **Figure 50**, the active work stages evaluated across the study freeway projects occur almost exclusively between March and November. No stages began before March 1st and approximately half of all active work stages begin before the end of May. While there is a spike in the number of stages starting in the fall, these are primarily the final close out stages of projects. Similarly, almost 90 percent of the active work stages in the study end before December 1st. There were only rare cases where significant temporary traffic control was in place over the winter shutdown period.

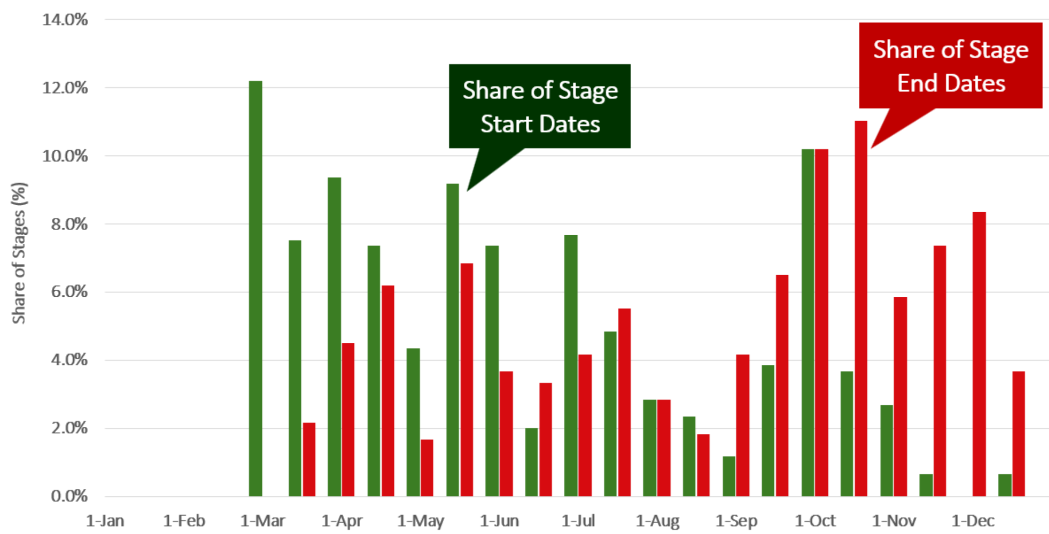


Figure 50. Share of Stages in Study Data by Two-Week Calendar Period

In other words, the overwhelming majority of Michigan freeway construction activity occurs between March and November in a typical year. It is critical to consider this March through November construction-season when evaluating work zone safety performance in Michigan as the snowy and icy pavement conditions that are present during the winter season influence safety performance. **Table 65** summarizes aggregate crash rates by type for (1) all periods in the study regardless of work zone condition or season, (2) periods where no work was occurring for the entire year, and (3) periods where no work was occurring during the March through November construction-season.

Table 65. Naïve, Normal Operations, and Construction-Season Crash Rates by Crash Type

Condition	VMT	Crash Rate per 100M VMT							
		Single Vehicle	Head On	Angle	Rear End	Side-swipe Same	Side-swipe Opp.	Other	Total
Naïve (***All Study Data***)	40,966,692,573	30.8	0.2	0.4	26.8	17.7	0.1	4.6	80.6
Normal Operations (***No Active Work Zones***)	22,100,523,856	30.3	0.2	0.5	27.4	16.4	0.1	4.8	79.7
Construction-Season Normal Operations (***March-Nov. w/ No Work Zones***)	16,575,392,892	23.3	0.1	0.4	27.9	15.1	0.1	4.2	71.1

While the rates of multiple vehicle collisions are similar across all periods, the rate of single vehicle crashes is considerably lower during the construction-season (23.3) compared to all months where no work was ongoing (30.3). This drives the total motor vehicle crash rate to be considerably lower during the construction-season (71.1 versus 79.7), demonstrating the importance of this seasonal change in safety performance.

The magnitude of these differences in construction-season versus winter-season safety performance also varies across the four categories of freeways under normal operations outlined previously in **Section 4.2**. As shown in **Table 66**, freeways located in rural and suburban areas tended to have a higher share of the total annual number of crashes occurring in the winter and thus larger disparities in construction-season versus winter-season crash rate.

Table 66. Construction-Season vs. Winter-Season Crash Rates under Normal Operations

Category	Projects	Min AADT	Max AADT	Impact Area Length	Crash Rates per 100M VMT						Winter Season Crashes as % of Total Annual Crashes
					Construction-Season			Winter-Season			
					Crashes	VMT	Rate	Crashes	VMT	Rate	
Urban Freeway Reconstruction Projects with Major Volume Impacts	2	106,400	114,900	71.8	4,502	5,097,181,316	**88.3**	1,836	1,699,060,439	**108.1**	**29.0%**
High AADT Suburban and Urban Freeways with Regular Recurring Congestion	5	48,200	72,826	161.6	4,239	5,516,774,185	**76.8**	2,217	1,838,924,728	**120.6**	**34.3%**
Moderate AADT Rural and Suburban Freeways with Low Recurring Congestion	9	25,400	66,200	173.4	2,642	4,759,780,035	**55.5**	1,495	1,586,593,345	**94.2**	**36.1%**
Low AADT Rural Freeways with Rare Congestion	8	6,000	19,100	160.2	408	1,201,657,356	**34.0**	275	400,552,452	**68.7**	**40.3%**
All Sites (*Excluding I-75 Modernization Project*)	**24**	**6,000**	**114,900**	**566.8**	**11,791**	**16,575,392,892**	**71.1**	**5,823**	**5,525,130,964**	**105.4**	**33.1%**

4.3.2 Analytical Methods

The estimated impact on safety performance associated with the construction activity was assessed consistent with the literature summarized in **Section 2.1.1** in a manner that considered the seasonal effect present in Michigan described above. The estimated impact on motor vehicle crash frequency (δ) was calculated for each study segment and each stage of the work by taking the difference between the number of observed crashes during the work period (λ) and the expected number of crashes without the work zone (π):

$$\boldsymbol{\delta = \lambda - \pi} \qquad \textbf{(Eq. 5)}$$

The number of observed crashes during the work period (λ) included all motor vehicle crashes occurring between the dates of each stage within the boundaries of each study segment as outlined in **Section 4.1.3**. The expected number of crashes without the work zone (π) was calculated via the EB method presented in the HSM [*14*], shown in **Figure 51**.

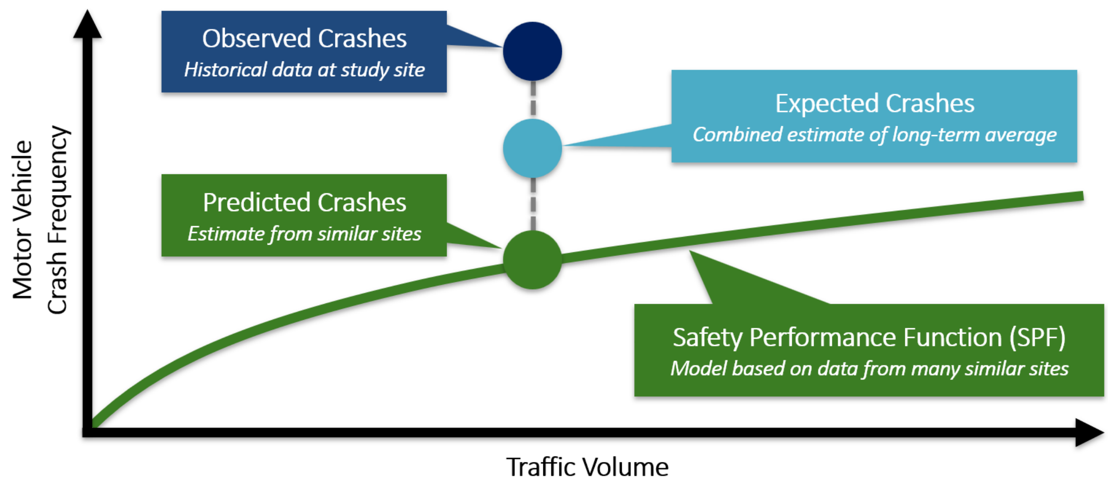


Figure 51. Process to Estimate Expected Number of Crashes under Normal Operations

For each segment, expected number of crashes without the work zone (π) was estimated by combining the observed number of crashes during the periods identified as normal operations (before the work zone was in place) with a predicted number of crashes estimated using data from similar sites under normal operation. The observed number of crashes under normal operations for each segment was determined by examining the number of crashes during the normal operations period, and adjusting based on traffic volumes observed during the work period. The predicted number of crashes under normal operations was estimated based on a series of four SPFs developed using normal operations data from all 24 sites.

It is important to note that distinct values for observed and predicted crash frequencies under normal operations were estimated for active work stages and winter shutdown periods in order to accommodate the seasonal differences in safety performance presented in **Table 66**. For active work stages, the expected number of crashes without the work zone (π) was based on a combination of observed crash data at the site (March through November under normal operations) and predicted values estimated via one of two construction-season SPFs. For winter shutdowns, expected number of crashes without the work zone (π) was based on a combination of observed crash data at the site (December through February under normal operations) and predicted values estimated via one of two winter-season SPFs. For rare stages that included both construction-season and winter-season periods, a blended approach was used that considered all months of observed data as well as both the construction- and winter-season SPFs.

A series of negative binomial regression models were estimated to develop four SPFs that relate the annual number of motor vehicle crashes along a freeway segment within a specific period to other roadway characteristics. This represents the predicted value in **Figure 51**. The negative binomial was employed, or a generalized form of the Poisson model. In the Poisson regression model, the probability of freeway segment i experiencing y_i motor vehicle crashes during a specific period is given by:

$$P(y_i) = \frac{EXP(-\lambda_i)\lambda_i^{y_i}}{y_i!} \qquad \textbf{(Eq. 6)}$$

where $P(y_i)$ is probability of segment i experiencing y_i crashes during the period and λ_i is equal to the segment's expected number of crashes, $E[y_i]$. Poisson regression models are estimated by specifying this Poisson parameter λ_i as a function of several explanatory variables. The most common functional form of this equation is $\lambda_i = EXP(\beta X_i)$, where X_i is a vector of explanatory variables (such as traffic volume or roadway context) and β is a vector of estimable parameters. The negative binomial model is derived by rewriting the Poisson parameter for each freeway segment i as $\lambda_i = EXP(\beta X_i + \varepsilon_i)$, where $EXP(\varepsilon_i)$ is a gamma-distributed error term with mean 1 and variance α. The addition of this term allows the variance to differ from the mean as $VAR[y_i] = E[y_i] + \alpha E[y_i]2$. The α term is also known as the overdispersion parameter, which is reflective of the additional variation in crash counts beyond the Poisson model (where α is assumed to equal zero or the mean and variance are assumed to be equal). Segment length was included as an offset and a segment-specific random effect was also included to accommodate the fact that each segment includes observations for each year available for analysis within the normal operations period. This repeated-measure study design introduces potential correlation between crash counts at each segment over time due to site-specific factors which are not included in the model, leading to biased, inefficient, or inconsistent parameter estimates without accommodation.

Table 67 provides results for four distinct negative binomial regression models used to estimate predicted crash values as a part of the process to calculate the expected number of crashes without the work zone (π). Construction-season (March-November) and winter-season (December-February) models are developed for freeways both with and without recurring congestion under normal operations (where no work zone is present). This is consistent with the findings presented in **Section 4.2.2**, where the initial condition of the facility under normal operations (or the current level of congestion and related motor vehicle crashes) influenced the relative impact on safety performance due to the work activity.

Table 67. Negative Binomial Model Results for Crash Occurrence under Normal Operations

Scenario	Time Period	Parameter	Estimate	Std. Error	Significance
Freeways **with** Regular Recurring Congestion	Construction-Season (*Mar-Nov*)	Intercept	-17.535	1.686	< 0.001
		Annual Average Daily Traffic (*In Vehicles per Day*)	1.836	0.157	< 0.001
		Suburban Freeways	0.626	0.135	< 0.001
		Overdispersion Parameter	0.251	na	na
	Winter-Season (*Dec-Feb*)	Intercept	-12.900	1.665	< 0.001
		Annual Average Daily Traffic (*In Vehicles per Day*)	1.337	0.155	< 0.001
		Suburban Freeways	0.505	0.134	< 0.001
		Overdispersion Parameter	0.248	na	na
Freeways **without** Regular Recurring Congestion	Construction-Season (*Mar-Nov*)	Intercept	-8.281	1.265	< 0.001
		Annual Average Daily Traffic (*In Vehicles per Day*)	0.947	0.125	< 0.001
		Rural Low Volume Freeways with Rare Congestion	-0.550	0.192	0.004
		Overdispersion Parameter	0.281	na	na
	Winter-Season (*Dec-Feb*)	Intercept	-6.170	1.306	< 0.001
		Annual Average Daily Traffic (*In Vehicles per Day*)	0.683	0.130	< 0.001
		Rural Low Volume Freeways with Rare Congestion	-0.681	0.201	< 0.001
		Overdispersion Parameter	0.301	na	na

Congested freeways located within suburban areas tended to experience more motor vehicle crashes after controlling for traffic volume than in urban areas. Along uncongested freeways, rural freeways with rare congestion tended to experience fewer motor vehicle crashes than in suburban areas after controlling for traffic volume. **Figures 52-55** provide SPFs based on each of the four models that relate crashes per mile per day to daily traffic volume, where the contextual indicator variables have been set to their average values.

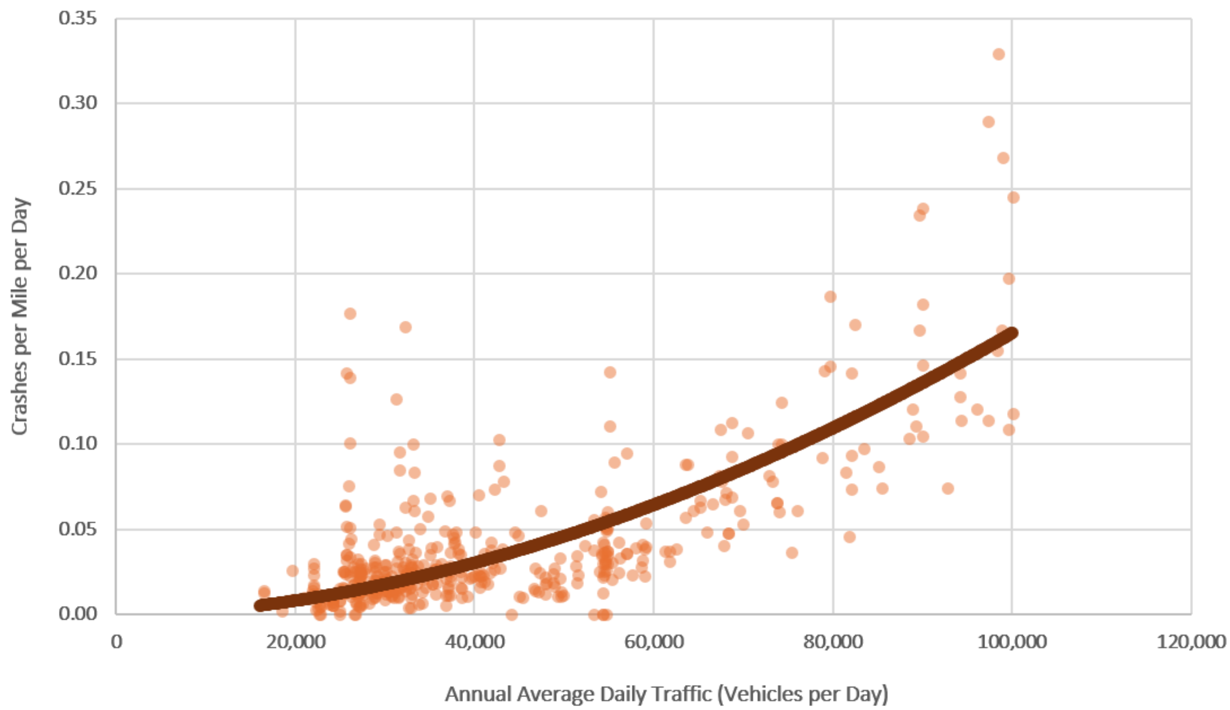


Figure 52. Construction-Season Congested Freeway Safety Performance under Normal Operations: Crashes per Mile per Day versus Annual Average Daily Traffic Volume

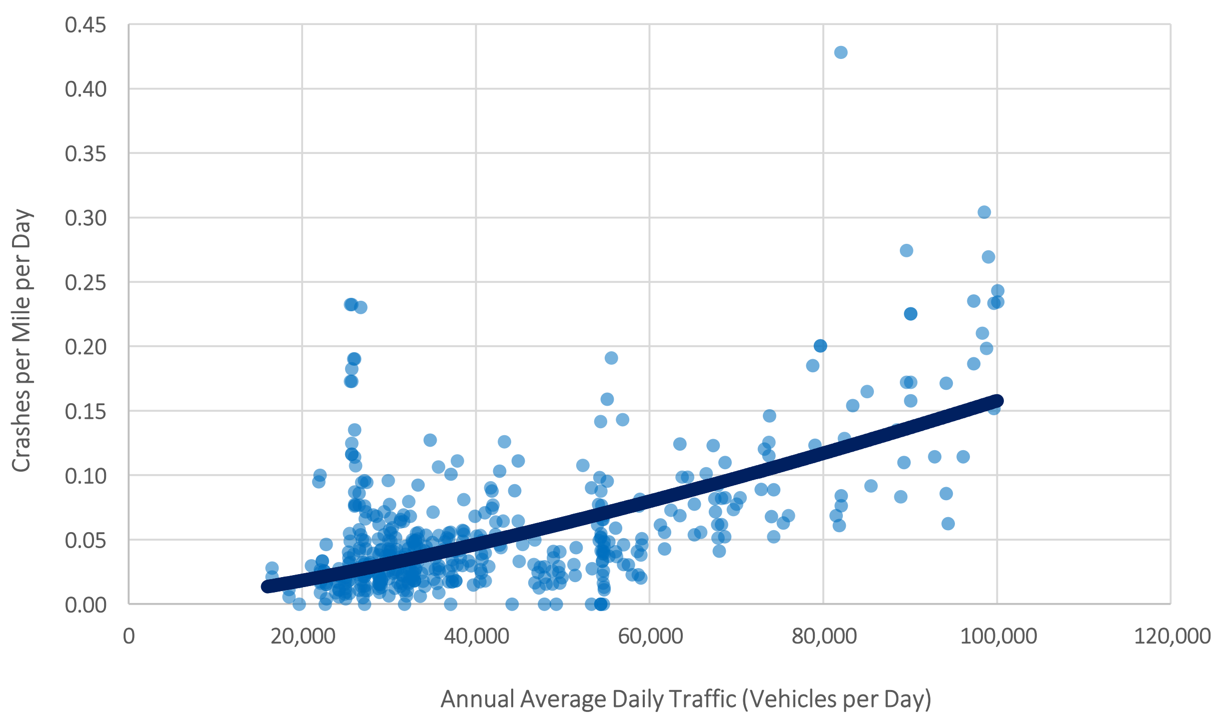


Figure 53. Winter-Season Congested Freeway Safety Performance under Normal Operations: Crashes per Mile per Day versus Annual Average Daily Traffic Volume

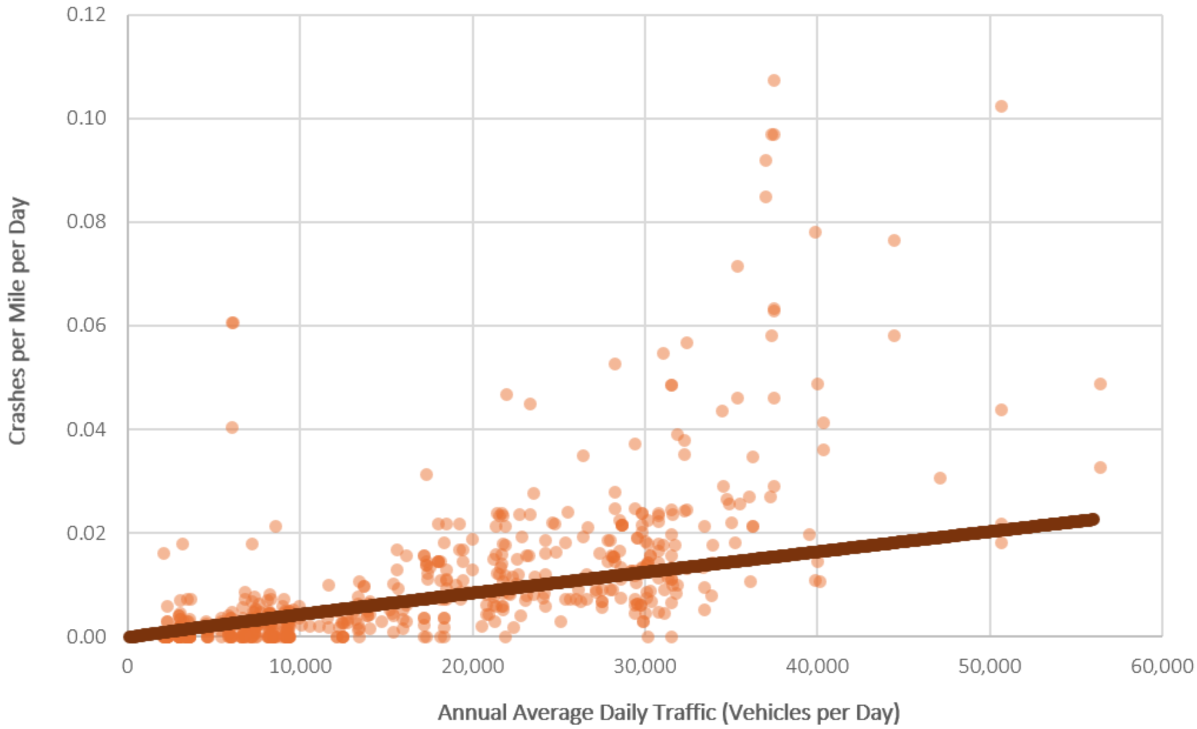


Figure 54. Construction-Season Uncongested Freeway Safety Performance under Normal Operations: Crashes per Mile per Day versus Annual Average Daily Traffic Volume

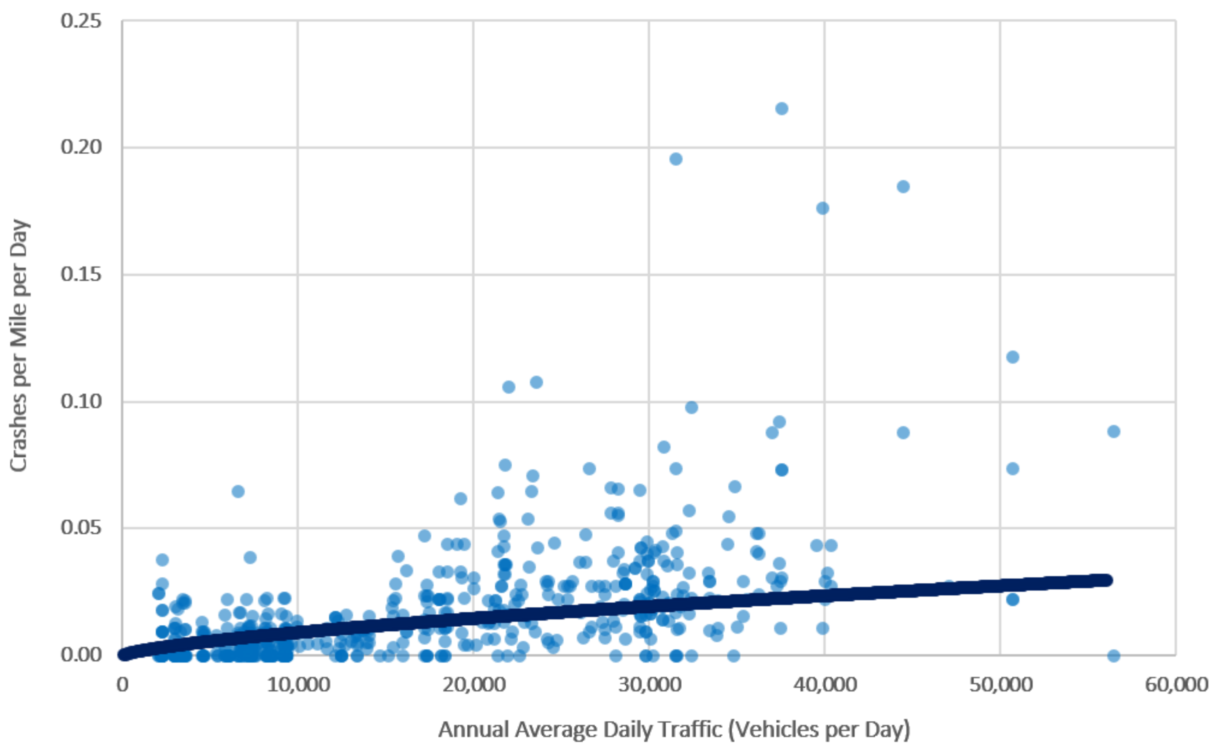


Figure 55. Winter-Season Uncongested Freeway Safety Performance under Normal Operations: Crashes per Mile per Day versus Annual Average Daily Traffic Volume

4.3.3 Estimated Impacts on Safety Performance

The following subsections summarize the estimated safety performance impacts by project, work area, and type of activity given the methods outlined in **Section 4.3.2**.

4.3.3.1 Estimated Change in Crashes During Work Operations by Project

The overall estimated impact on motor vehicle crashes for each project is summarized in **Table 68**. It should be noted that the results presented in **Table 68** incorporate the entire study corridor (including upstream, advance warning, and downstream areas as shown in **Figure 40**) as opposed to only the active work areas. Conceptually, this is similar to MDOT's construction influence area included within the special provision for maintaining traffic. In other words, the results presented in **Table 68** represent the impact of the project as a whole (including winter shutdown periods and adjacent facilities). Findings for each of the four normal operations categories are also presented in **Table 69**.

Table 68. Estimated Change in Crashes during Work Zone Operations by Project

Project	Region	AADT	Context	Impact Area Length	Work Days	Crashes during Normal Operations			Crashes during Work Zone Operations		
						Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
I-96 (Kent Lake to I-275)*	Metro	114,900	Urban	28.6	651	974.1	906.9	915.7	1,271.0	+355.3	38.8%
I-275 (M-153 to 5 Mile Road)*	Metro	106,400	Urban	43.2	908	1,784.9	1,959.6	1,964.0	2,336.0	+372.0	18.9%
I-75 (M-15 to Oakland County Line)*	Metro	72,826	Urban	60.5	224	289.9	348.8	342.4	402.0	+59.6	17.4%
I-94 (Lovers Lane to Sprinkle Road)	Southwest	70,000	Urban	14.3	929	309.5	436.9	420.0	480.0	+60.0	14.3%
US-23 (Stoney Creek Road to Ellsworth Road)*	University	66,200	Suburban	23.8	306	125.1	149.4	147.7	249.0	+101.3	68.6%
I-75 (Erie Road to Otter Creek)*	University	59,200	Rural	20.0	602	228.8	239.4	236.1	315.0	+78.9	33.4%
I-75 (Hess Avenue to I-675 Interchange)	Bay	56,200	Suburban	15.7	858	237.7	255.5	250.7	324.0	+73.3	29.2%
I-94 (Britain Avenue to I-196 Interchange)	Southwest	56,000	Suburban	12.2	577	199.9	152.0	158.3	179.0	+20.7	13.1%
US-23 (I-96 to Livingston County Line)	University	54,000	Suburban	44.8	476	603.4	560.4	569.3	564.0	-5.3	-0.9%
I-196 (Byron Road to 32nd Avenue)	Grand	50,000	Suburban	22.9	610	216.5	246.3	239.5	230.0	-9.5	-4.0%
I-94 (Blackman Road to Sargent Road)	University	48,200	Suburban	29.7	800	490.7	579.2	570.5	599.0	+28.5	5.0%
I-75 (State Line to Erie Road)	University	46,900	Rural	16.6	543	129.9	130.7	130.0	260.0	+130.0	100.0%
I-94 (Red Arrow Highway to Stevensville)	Berrien	43,600	Suburban	13.0	206	33.2	32.3	32.5	44.0	+11.5	35.4%
US-131 (M-179 Interchange)	Grand	38,500	Rural	16.2	610	104.0	112.5	110.4	150.0	+39.6	35.8%
US-31 (I-196 NB to Central Avenue)	Grand	28,500	Suburban	10.0	218	13.0	11.6	12.4	10.0	-2.4	-19.0%
I-69 (M-24 to Lake George Road)	Bay	25,400	Suburban	22.1	608	154.7	84.2	108.6	93.0	-15.6	-14.3%
US-131 (13 Mile Road to 19 Mile Road)	Grand	19,100	Rural	11.8	111	4.2	4.5	4.4	9.0	+4.6	105.8%
I-75 (Ogemaw County Line to Cook Road)	North	15,500	Rural	23.7	220	12.6	17.9	15.2	24.0	+8.8	58.2%
I-69 (M-19 to Cox-Doty Drain)	Bay	14,600	Rural	26.8	262	18.6	14.2	16.6	18.0	+1.4	8.3%
I-75 (Old M-108 to Mackinac Bridge)	North	11,400	Rural	7.8	236	3.9	5.0	4.3	12.0	+7.7	179.3%
I-75 (M-27 to Topinabee Mail Route)	North	10,000	Rural	6.9	229	3.2	2.2	2.8	4.0	+1.2	42.9%
I-75 (Levering Road to US-31)*	North	8,600	Rural	15.8	569	35.5	20.2	30.6	33.0	+2.4	7.7%
US-127 (M-55 to Muskegon River Bridge)	North	7,780	Rural	15.2	166	3.5	3.6	3.5	9.0	+5.5	156.8%
I-75 (M-80 to M-28)	Superior	6,000	Rural	20.9	166	3.5	4.4	3.7	7.0	+3.3	86.8%

Project remains ongoing beyond 2016-2023 study period

Table 69. Estimated Change in Crashes during Work Zone Operations by Project Category

Category	Projects	Min AADT	Max AADT	Impact Area Length	Work Days	Crashes during Normal Operations			Crashes during W.Z. Operations		
						Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Urban Freeway Reconstruction Projects with Major Volume Impacts	2	106,400	114,900	71.8	1,559	2,759.0	2,866.5	2,879.6	3,607.0	**+727.4**	**25.3%**
High AADT Suburban and Urban Freeways with Recurring Congestion	5	48,200	72,826	161.6	3,006	1,893.4	2,077.4	2,060.5	2,224.0	**+163.5**	**7.9%**
Moderate AADT Rural and Suburban Freeways with Low Recurring Congestion	9	25,400	66,200	173.4	4,561	1,242.8	1,262.0	1,267.9	1,675.0	**+407.1**	**32.1%**
Low AADT Rural Freeways with Rare Congestion	8	6,000	19,100	160.2	1,959	85.1	72.0	81.2	116.0	**+34.8**	**42.9%**
All Sites (*Excluding I-75 Modernization Project*)	**24**	**6,000**	**114,900**	**566.8**	**11,085**	**5,980.4**	**6,277.9**	**6,289.2**	**7,622.0**	**+1332.8**	**21.2%**

In total, 20 of the 24 projects experienced more crashes during the work period than expected without the work zone present (or a relative increase in crashes). Construction projects along rural freeways experienced the five largest relative increases, including the largest increase (179.3 percent) associated with the I-75 project near the Mackinac Bridge (see **Appendix A.5** for more information). A total of 1,332.8 additional motor vehicle crashes occurred during the work periods, representing a 21.2 percent increase on the expected number of crashes along these facilities without the work zone present (but given the work zone traffic volume).

While the findings presented in **Table 68** are in general agreement with the naïve crash rates presented in **Table 52**, there are some key differences highlighted by the analytical approach that considered the seasonal changes in safety performance. This is particularly true for the projects that impacted the freeway facilities that typically do not experience regular recurring congestion under normal operations. The EB method results suggested larger relative changes than the naïve analysis for the nine moderate volume projects (32.1 percent) and eight low volume rural projects (42.9 percent). This is in part due to these sites experience relatively large differences in winter-season safety performance under normal operations (as shown in **Table 53**) that was better accommodated by the analytical approach outlined in **Section 4.3.2**.

The two urban freeway projects (along I-96 and I-275) where traffic volumes exceed 100,000 vehicles per day under normal conditions experienced considerable reductions in capacity during the work period. As a result, the 727.4 additional crashes that are estimated to have occurred during the work period represent a 25.3 percent increase over normal operations.

This degradation in safety performance is greater than the remaining five urban or suburban freeway projects that regularly experience congestion under normal operations. These projects experienced an additional 163.5 motor vehicle crashes, representing a smaller relative 7.9 percent increase. Consistent with the findings presented in **Table 66**, construction-season and winter-season safety performance varies less along these facilities with recurring congestion and therefore these results are closer to the naïve findings presented in **Table 53 of Section 4.2.2**.

4.3.3.2 Estimated Change in Crashes during Work Zone Operations by Area within the Work Zone

The estimated impact on motor vehicle crashes by work area is summarized in **Tables 70 and 71**, consistent with the definitions provided in **Table 50 of Section 4.1**. Distinct results are provided for projects along freeways that regularly experience recurring congestion under normal operations (**Table 70**) and freeways that do not regularly experience such congestion (**Table 71**). It is important to note that winter shutdown periods have been removed. Consistent with **Table 69**, the relative impact on safety performance was larger for freeways that do not typically experience recurring congestion under normal operations (47.9 percent) than for freeways where such congestion is commonly present (24.5 percent).

Table 70. Estimated Change in Crashes During Work Zone Operations by Area within the Work Zone (*Congested Freeways under Normal Operations*)

Work Area	VMT	Crashes during Normal Operations			Crashes during Work Zone Operations		
		Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Upstream	255,057,876	214	250	249	237	-12.2	-4.9%
Advance Warning	603,551,498	494	503	506	553	+47.4	9.4%
Transition	14,135,820	9	14	13	18	+5.0	38.4%
Activity	3,438,609,960	2,862	3,136	3,107	4,155	+1047.8	33.7%
Termination	30,017,604	19	30	28	16	-12.0	-42.8%
Downstream	394,921,493	328	368	368	340	-27.6	-7.5%
All Work Areas	4,736,294,250	3,925	4,301	4,271	5,319	+1048.4	24.5%

Table 71. Change in Crashes During Work Zone Operations by Area within the Work Zone (*Uncongested Freeways under Normal Operations*)

Work Area	VMT	Crashes during Normal Operations			Crashes during Work Zone Operations		
		Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Upstream	256,893,271	130	151	149	167	+18.3	12.3%
Advance Warning	241,388,114	128	137	138	200	+61.7	44.6%
Transition	37,989,774	20	19	19	55	+35.9	188.5%
Activity	1,110,117,074	579	579	583	935	+352.1	60.4%
Termination	33,063,112	18	20	20	30	+9.7	47.6%
Downstream	262,954,606	134	118	121	137	+15.9	13.1%
All Work Areas	1,942,405,952	1,008	1,023	1,030	1,524	+493.6	47.9%

While crashes were slightly elevated within the upstream areas of the projects along uncongested freeways, there was little overall change in safety performance within upstream areas compared to the expected crash frequency without the work zone present. Similar results can also be observed for downstream and transition areas. Ultimately, freeway construction efforts are not having large impacts on safety performance within these portions of the construction influence area. However, there were specific instances among the 24 projects where safety performance was considerably impacted within these areas (such as scenarios where queues may spill over into upstream areas beyond the advance warning area). For example, the project profile presented in **Appendix A.20** for the split merge project along US-23 demonstrates increases in the upstream area in both directions. Safety performance was degraded within advance warning areas for projects along both congested and uncongested freeways. However, the magnitude of this effect was much larger for uncongested facilities (44.6 percent) versus congested facilities (9.4 percent).

Safety performance within transition areas degraded for both projects along congested (38.4 percent) and uncongested (188.5 percent) freeway facilities. While the sample size of crashes during the work activity (73) suggests these findings should be interpreted with caution, the findings presented in **Table 72** provide evidence that safety performance is considerably decreased within transition areas. While this effect is particularly pronounced for projects along uncongested facilities, **Table 72** also demonstrates that the type of transition area also may impact safety performance. For example, transitions to split merge configurations experienced the largest relative increase in crash frequency.

Table 72. Change in Crashes during Work Zone Operations by TTC Configuration

Temporary Traffic Control Configuration	VMT	Crashes during Normal Operations			Crashes during Work Zone Operations		
		Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Closure of Shoulders	2,253,067	1.2	1.5	1.4	2.0	**+0.6**	**38.3%**
Lane Shifts	11,827,109	6.4	7.2	7.0	15.0	**+8.0**	**114.5%**
Lane Closures	20,886,366	12.2	13.7	13.7	31.0	**+17.3**	**126.8%**
Vehicles Crossed Over	13,311,336	7.7	8.1	8.2	18.0	**+9.8**	**120.7%**
Transition to Split Merge	3,847,715	2.0	1.8	1.8	7.0	**+5.2**	**288.1%**
All Transition Areas	**52,125,593**	**29.5**	**32.3**	**32.1**	**73.0**	**+40.9**	**127.7%**

With respect to activity areas, projects along uncongested freeways again experienced considerably larger relative increases in motor vehicle crashes (60.4 percent) compared to projects along congested freeways (33.7 percent). The type of activity also played a critical role in the relative change in safety performance, as shown in **Tables 73 and 74**. It should be noted that additional work types beyond those presented within **Tables 73 and 74** were included within evaluation but did not have large enough sample sizes to evaluate via the analytic methods presented outlined in **Section 4.3.2**. Refer to the project profiles presented in **Appendix A** for more information on specific work types beyond those presented in **Tables 73 and 74**.

Table 73. Estimated Change in Crashes During Work Zone Operations by MOT at the Activity Area (*Congested Freeways under Normal Operations*)

Temporary Traffic Control Configuration	VMT	Crashes during Normal Operations			Crashes during Work Zone Operations		
		Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Lane Shifts or Shoulder Closures	50,652,393	32.1	55.6	52.7	60.0	**+7.3**	**13.8%**
Lane Closures	443,068,186	297.8	277.4	279.1	390.0	**+110.9**	**39.7%**
Crossovers	157,599,657	112.2	155.1	149.9	189.0	**+39.1**	**26.1%**

Table 74. Estimated Change in Crashes During Work Zone Operations by MOT at the Activity Area (*Uncongested Freeways under Normal Operations*)

Temporary Traffic Control Configuration	VMT	Crashes during Normal Operations			Crashes during Work Zone Operations		
		Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Intermittent Lane Closures	268,250,322	143.4	151.4	150.5	189.0	**+38.5**	**25.5%**
Long-Term Lane Closures	184,852,417	91.1	84.6	85.5	182.0	**+96.5**	**112.9%**
Crossovers or Split Merge	488,187,558	259.0	239.3	246.0	429.0	**+183.0**	**74.4%**

Intuitively, lane shifts or shoulder closures represented only modest changes to safety performance for projects along congested freeways (13.8 percent). Lane closures (39.7 percent) and crossovers (26.1 percent) along congested facilities represented considerably larger impacts on safety performance. **Figure 56** provides a series of SPFs that are estimated based on the findings presented in **Tables 70 and 73** for projects along freeways that regularly experience recurring congestion that relate crashes per mile per day to daily traffic volume.

There was a wider range of relative impacts on safety performance among the freeway facilities without recurring congestion under normal operations. Intermittent lane closures (or scenarios where lane closures are implemented along limited portions of an activity area over a single stage) were associated with more modest relative impacts (25.5 percent) than long-term lane closures (112.9 percent) or traffic control configurations that included a crossover (74.4

percent). It should be noted that the long-term lane closures included scenarios where a lane closure is implemented over the entire length of the activity area for the entire stage. Crossover configurations included conventional crossovers with temporary barrier as well as split merge and moveable barrier wall configurations. **Figure 57** provides a series of SPFs that are estimated based on the findings presented in **Tables 71 and 74** for projects along uncongested facilities.

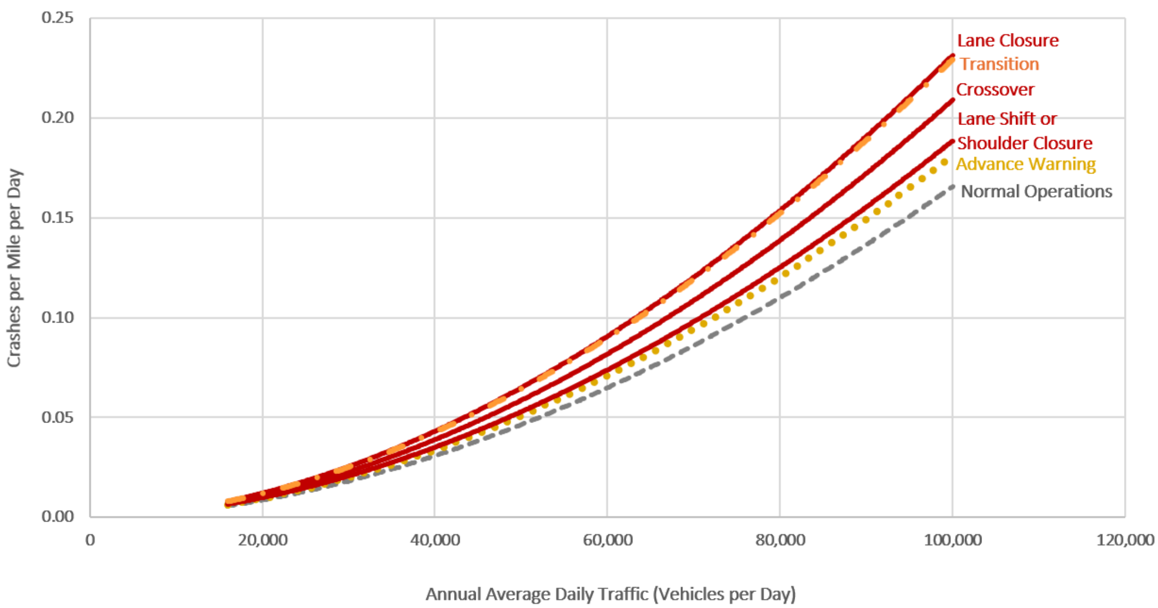


Figure 56. Congested Freeway Safety Performance by Work Area: Crashes per Mile per Day versus Annual Average Daily Traffic Volume

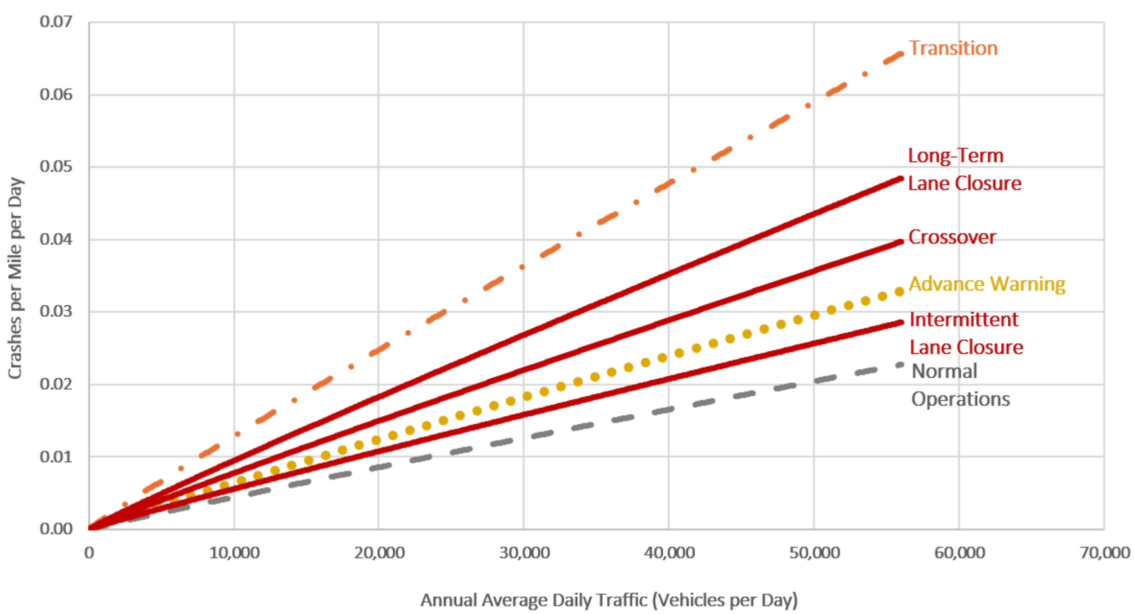


Figure 57. Uncongested Freeway Safety Performance by Work Area: Crashes per Mile per Day versus Annual Average Daily Traffic Volume

5.0 CONCLUSIONS AND RECOMMENDATIONS

Despite the fact that highway work zones represent a required element of maintaining and improving the transportation network, the resulting changes in traffic patterns, narrowed right-of-way, and other construction activities can lead to an increased risk for traffic crashes and related injuries or fatalities [*1*]. Consistent with MDOT's commitment to the Safe System Approach [*271*], the department sponsored research project OR23-022 (*Optimizing Work Zone Conditions to Maximize Safety and Mobility*) to identify the critical work zone attributes that are related to improved (or degraded) work zone safety and/or mobility, and ultimately identify cost effective treatments that can achieve high levels of both safety and mobility. **Chapters 2-4** summarize the efforts to fulfill the project objectives outlined within **Section 1.2**.

The outcomes of the research include a synthesis of prior research and best practices used by other agencies, a benchmark of statewide work zone safety performance, new tools and resources to conduct safety analyses specific to freeway work zones, and recommendations to improve MDOT's work zone program (including recommendations for MDOT's W*ork Zone Safety and Mobility Manual* [*6*]). **Section 5.1** provides a summary of key findings from this research, which are based on the results of the literature review, statewide crash data evaluation, and safety performance analysis for select freeways presented in **Chapters 2-4**. **Section 5.2** details 17 specific recommendations related to MDOT's work zone resources and practices that were derived from the research findings.

5.1 Key Findings Related to Work Zone Safety Performance in Michigan

Table 75 provides a summary of the key research findings that are detailed across **Chapters 2-4**, where the findings are presented by roadway type.

Table 75. Key Findings Related to Work Zone Safety Performance in Michigan

Roadway Type	Finding
All Roadways	• Michigan has experienced an annual average of approximately 5,150 construction or maintenance work zone-coded traffic crashes per year, including approximately 17 collisions resulting in a fatality and 65 collisions resulting in a serious injury.

Roadway Type	Finding
All Roadways	• Statewide work zone-coded crash totals are less sensitive to overall travel trends compared to total crash frequency. Instead, statewide work zone-coded crash totals are largely driven by the amount of roadwork conducted in any given year. • When compared to the national experience, Michigan tends to observe a larger proportion of rear end work zone collisions and a smaller proportion of single vehicle collisions. • Fatal and serious injury work zone collisions become more common in dark conditions with or without lighting present. • Data from the analysis of freeway work zones presented in **Chapter 4** suggested a considerable underreporting of work zone crashes. Further, **Chapter 4** also demonstrates that there is considerable error within the newly added work zone fields (in particular the construction activity and location fields). While these findings were specific to freeway projects, similar trends are also likely to be present along non-freeway facilities. • Data from the analysis of freeway work zones presented in **Chapter 4** provides evidence that construction-season (March-November) and winter-season (December-February) safety performance varies due to increased rates of single-vehicle crashes observed in the winter. As a result, it is critical to consider such seasonal patterns when conducting work zone safety performance analysis in Michigan.
Freeways	• Michigan has experienced an annual average of approximately 2,200 freeway work zone-coded traffic crashes per year, including approximately 11 collisions resulting in a fatality and 27 collisions resulting in a serious injury. • Nearly half of fatal freeway work zone crashes in Michigan are rear end collisions, compared to approximately one-third of fatal work zone crashes nationwide. • The existing operational conditions along freeway facilities under normal operations (before the implementation of work zone temporary traffic control) has a dramatic effect on the relative impact of a work zone on safety performance. Facilities that experience consistent recurring congestion under normal operations tended to experience smaller relative impacts than facilities where such recurring congestion is uncommon. o The analysis presented in **Section 4.3** provides distinct tools to conduct work zone safety performance analysis for both conditions. • Construction projects along rural freeways experienced the five largest relative increases in crashes out of the 24 projects evaluated, including the largest increase (179.3 percent) associated with the I-75 project near the Mackinac Bridge. • The rate of rear end collisions was considerably larger than under normal operations as vehicles enter the upstream area, traverse the advance warning area, and enter the activity area. Rates of rear end collisions were highest within the activity areas (as opposed to in advance of the work zone). Ultimately, concentrations of rear end collisions related to vehicles stopping or slowing within the work zone tended to occur wherever triggers for unstable flow may be present. • Overall aggregate safety performance within upstream, downstream and termination areas was not influenced by work zone temporary traffic control.

Roadway Type	Finding
	o However, there were specific instances among the 24 projects evaluated where safety performance was considerably impacted within these areas (such as scenarios where queues may spill over into upstream areas beyond the advance warning area). • The relative impact on crash frequency within advance warning areas was 9.4 percent for congested facilities and 44.6 percent for uncongested facilities. • The relative impact on crash frequency within transition areas was 38.4 percent for congested facilities and 188.5 percent for uncongested facilities. This was driven by increases in the rate of single vehicle and sideswipe same crashes compared to safety performance under normal operations. • With respect to activity areas, projects along uncongested freeways again experienced considerably larger relative increases in motor vehicle crashes (60.4 percent) compared to projects along congested freeways (33.7 percent). The type of activity also played a critical role in the relative change in safety performance, where **Figures 56 and 57 of Section 4.3.3** provide a series of SPFs can be used to estimate expected safety performance by activity type. • The share of truck-involved crashes was considerably higher within transition, activity, and termination areas compared to other work areas or normal conditions. • Work zone crashes occurring along freeway ramps or other freeway segments that comprise complex interchanges represent only seven percent of all freeway work zone collisions. Additionally, the data presented within **Section 4.2.3** demonstrate that ramp safety performance on the aggregate does not appear to be considerably degraded as a part of freeway construction efforts. • The resurfacing and reconstruction project along US-23 near Ann Arbor (detailed in **Appendix A.20**) included the use of a split merge configuration, which performed poorly in comparison to other conventional crossover configurations evaluated as a part of OR23-022. However, data from additional sites is needed to determine if there are statistically significant differences in safety performance versus other crossover configurations. • The I-75 modernization project represents a unique work zone scenario where crash rates observed along the corridor (173.5) are considerably higher than any other corridor evaluated as a part of OR23-022. Additionally, this complex effort occurred across the entire 2016 to 2023 study period and therefore it was not possible to employ the same analytical approach as the other 24 projects. **Appendix A.25** provides an overview of the safety performance observed across the project corridor during the study period. • The reconstruction project along I-75 near Levering Road included the use of a moveable barrier wall to crossover traffic, where the area with the moveable barrier wall experienced a 305.1 percent increase in motor vehicle crashes. However, data from additional sites is needed to determine if there are statistically significant differences in safety performance versus other crossover configurations. This is particularly important as MDOT has subsequently employed other approaches to the pavement markings and other elements of moveable barrier wall projects.

Roadway Type	Finding
Arterials	• Michigan has experienced an annual average of approximately 2,553 arterial work zone traffic crashes per year, including approximately 5 collisions resulting in a fatality and 31 collisions resulting in a serious injury. • Michigan has observed a higher share of fatal rear end work zone collisions (27.6 percent) compared to the national experience (12.6 percent). • Michigan has observed a higher share of fatal work zone crashes involving pedestrians (41.4 percent) than the national experience (16.0 percent). • A total of 154 arterial work zone crashes involving pedestrians or bicyclists occurred during the study period, including 57 incidents involving a road worker being struck by a vehicle. • A key safety concern is the interaction between flaggers and the driving public, where 21 collisions occurred that involved a vehicle striking either a flagger or disregarding flagger control and striking another road worker.
Collectors	• Michigan has experienced an annual average of approximately 212 collector work zone-coded traffic crashes per year, including approximately 1.3 collisions resulting in a fatality and 3.7 collisions resulting in a serious injury. • In contrast with the findings for mainline freeways and arterial roadways, rear end collisions comprise a far smaller share of all collector work zone crashes. • A total of 34 collector work zone-coded crashes involving pedestrians or bicyclists occurred during the six-year study period, including 23 incidents involving a road worker being struck by a vehicle. • A key safety concern for collector work zones remains the interaction between flaggers and the driving public, where 17 collisions occurred that involved a vehicle striking either a flagger or disregarding flagger control and striking another road worker.
Local Roadways	• Michigan has experienced an annual average of approximately 185 local roadway work zone-coded traffic crashes per year, including approximately 0.17 collisions resulting in a fatality and 2.8 collisions resulting in a serious injury. • In contrast with all of the other roadway types evaluated in this study, rear end collisions are not the predominant work zone crash type along local roadways. Instead, single vehicle, angle, and other collisions represent the most common crash type across a mix of work activities. • A total of 29 work zone crashes involving pedestrians or bicyclists occurred during the six-year study period, including 19 incidents involving a road worker being struck by a vehicle. • A key safety concern for local roadway work zones is the interaction between flaggers and the driving public, where 6 collisions occurred that involved a vehicle striking either a flagger or disregarding flagger control and striking another road worker.

5.2 Recommended Revisions to MDOT's Work Zone Resources and Practices

Based on the findings presented in **Table 75**, a series of 17 recommendations were developed for MDOT's consideration. These recommendations represent data-driven suggestions for existing MDOT policies, guidance, and other documents intended to improve safety and mobility within Michigan work zones. The recommendations are primarily focused on the MDOT *Work Zone Safety and Mobility Manual* [*6*], including a revised *Safety & Mobility Decision Tree* (discussed in **Table 76** and presented in **Figure 58)**.

Additionally, a *Microsoft Excel Freeway Work Zone Analysis Tool* (shown in **Figure 59**) was developed to support MDOT towards employing the findings presented within **Chapter 4**. A flowchart that provides an overview of the process to employ the tool is provided in **Figure 60**, where more detailed guidance for specific inputs and criteria can be found within the tool. References to the tool are also integrated within the recommendations presented in **Table 76**.

Table 76. Recommended Revisions to MDOT's Work Zone Resources and Practices

Resource	Recommendation
All Resources	The trends and patterns summarized within the statewide evaluation presented in **Chapter 3** identify areas for the department to target towards reducing both the frequency and severity of work zone collisions. It is critical to note there are a number of factors (including those beyond MDOT's approach to temporary traffic control) that could influence these patterns (such as differences versus other states in the police coding of crash data, the composition of the transportation system, and the types of projects that occurred during the study period). Ultimately, MDOT should seek opportunities within its work zone safety policies and procedures to: • Increase the use of strategies to reduce rear end collisions within all freeway and arterial work zones. See **Figure 27** for more information on fatal and serious injury rear end collisions in freeway work zones. Such countermeasures should be emphasized throughout the activity area in addition to the beginning of the work zone. • Address the patterns of fatal and serious injury collisions occurring within work zones at night with or without lighting present. • Ensure that appropriate focus is placed on rural freeway projects where recurring congestion is rare as these facilities experience the largest relative decrease in safety performance due to construction activities. • Emphasize safety performance for large trucks given the overrepresentation of truck-involved collisions within transition, activity, and termination areas of freeway projects compared to normal conditions. • Continue to emphasize MDOT's typicals specific to freeway ramps as safety performance along these facilities was largely unaffected during work periods. Design for freeways should focus on how ramps influence mainline performance (including the consideration of potential ramp closures).

Resource	Recommendation
	• Emphasize pedestrian safety performance along arterial work zones as Michigan has experienced a higher share of pedestrian work zone fatalities along these facilities than the United States as a whole. • Emphasize reducing conflicts between traffic regulators and drivers, as such collisions represented one of the most frequent types of collisions between vehicles and pedestrians within non-freeway work zones.
MDOT's *Work Zone Safety and Mobility Manual* [6] *and* *UD-10 Traffic Crash Report 2021 Instruction Manual* [268]	Given the considerable limitations associated with the reliability of the work zone fields included on UD-10 crash report forms demonstrated in **Section 4.2.2**, MDOT should avoid using these fields as a part of formal work zone safety analyses discussed within the *Work Zone Safety and Mobility Manual* unless the accuracy of these fields can be improved. Most importantly, the use of the construction type code to identify crashes occurring within a work zone should be minimized as this could lead to potential underreporting of related crashes. Instead, analysts should focus on all non-animal crash records occurring within construction influence areas when collecting traffic crash data as a part of work zone safety analysis (including when using the *Microsoft Excel tool*). Further, statewide stakeholders should seek to expand training for officers that yields more consistent use of these fields. Revisions to these fields could also be encouraged towards this goal.
MDOT's *Work Zone Safety and Mobility Manual* [6]	All work zone safety performance analysis outlined within the *Work Zone Safety and Mobility Manual* should consider the seasonal differences in safety performance observed between the construction-season (March-November) and winter-season (December-February). This is particularly important when comparing safety performance during periods under normal operations (before the work zone was in place) to periods where active work is underway. Analysts should also consider whether there are seasonal differences in traffic volume as a part of this process. Additionally, consider including a similar discussion within Section 4.01 of the manual. The crash data inputs within the *Microsoft Excel tool* are based on construction-season (March-November) consistent with **Section 4.3**.
MDOT's *Work Zone Safety and Mobility Manual* [6]	Freeway work zone safety performance analysis processes within the *Work Zone Safety and Mobility Manual* should consider the important differences in relative impacts to safety performance for freeways with and without recurring congestion under normal operations, as outlined in **Section 4.3**. While engineering judgement should be used to determine between uncongested versus congested facilities based on an operational analysis that considers factors beyond average daily traffic volume (such as peak hour factor), the department can generally consider facilities with above average total (71.1) and rear end (27.9) crash rates per 100 million vehicle miles traveled as congested. Consider including a similar conceptual discussion within Section 4.01 of the manual. This is also a required input for analysts to obtain output from the *Microsoft Excel tool*.
MDOT's *Work Zone Safety and Mobility Manual* [6]	Given that there was not enough information to estimate the safety performance impacts for a number of temporary traffic control configurations or design strategies beyond those outlined in **Section 4.3**, the department should continue to evaluate projects consistent with the methods outlined in **Section 4.1**. • For example, data from future projects that include specific temporary traffic control configurations (such as the use of moveable barrier walls) or ITS

<table>
<tr><th>Resource</th><th>Recommendation</th></tr>
<tr><td></td><td>strategies (such dynamic stopped traffic advisory systems) can be used to provide additional insight into these design elements.
Results from future freeway projects evaluated via the Microsoft Excel tool could be used to support this process.
Future research conducted by safety stakeholders within Michigan and within the traffic safety community nationwide can also be directly integrated with the data-driven safety performance analysis process outlined in Chapter 4 (and the Microsoft Excel tool).
This recommendation is consistent with Part B of Section 1.02.05 of MDOT’s Work Zone Safety and Mobility Manual which discusses the importance of retaining this information as a resource for future projects.</td></tr>
<tr><td>MDOT’s Work Zone Safety and Mobility Manual [6]</td><td>The data collection process, analytical tools, and project-level findings presented within Chapter 4 and Appendix A can be used to conduct data-driven safety performance analyses for freeway facilities in support of the required processes outlined within MDOT’s Work Zone Safety and Mobility Manual. For example, the SPFs presented within Figures 56 and 57 can be used to estimate the expected safety performance within freeway work zones. The Microsoft Excel tool can also be used to support this process. Additionally, the 25 project profiles presented within Appendix A also represent a resource to use as a part of seeking information related to similar recent projects. A list of the sections within the current edition of the manual that refer to work zone safety analysis are provided below for MDOT’s reference. However, it should be noted that many of these sections may not be directly impacted by recommendations from OR23-022 and may also change over time.
Section 1.02.01 (Scoping Transportation Management Plans)
Section 1.02.02 (Development Transportation Management Plans)
Section 1.02.05 – Part B (Work Zone Construction Peer Reviews)
Section 1.02.07 (Alternate Technical Concept Projects)
Section 1.02.08 – Part A (Region Engineer’s Approval Memo)
Section 2.04 (Work Zone Crash Analysis)
Section 2.05 (Design Crash Analysis)
Section 2.08 (Performance Assessment Plans)
Section 2.09 (FHWA Final Rule)
Section 2.10 (Work Zone Monitoring)
Section 2.10.01 (Work Zone Field Reviews)
Section 2.10.03 (Work Zone Crashes)
Section 2.10.04 (Work Zone Crashes during Construction)
Section 2.10.10 (Statewide Work Zone Crash Evaluation)
Section 2.10.12 (Project Review)
Section 4.01 (General – Work Zone Safety)
Section 4.05 (Work Zone Law Enforcement)
Section 6.05.11 – Part A (Traffic Switches)</td></tr>
<tr><td>MDOT’s Work Zone Safety and Mobility Manual [6]</td><td>Section 1.05 of the manual discusses annual work zone training activities completed during off-peak construction times. Findings from OR23-022 could be used to support these training activities, including details on conducting work zone safety</td></tr>
</table>

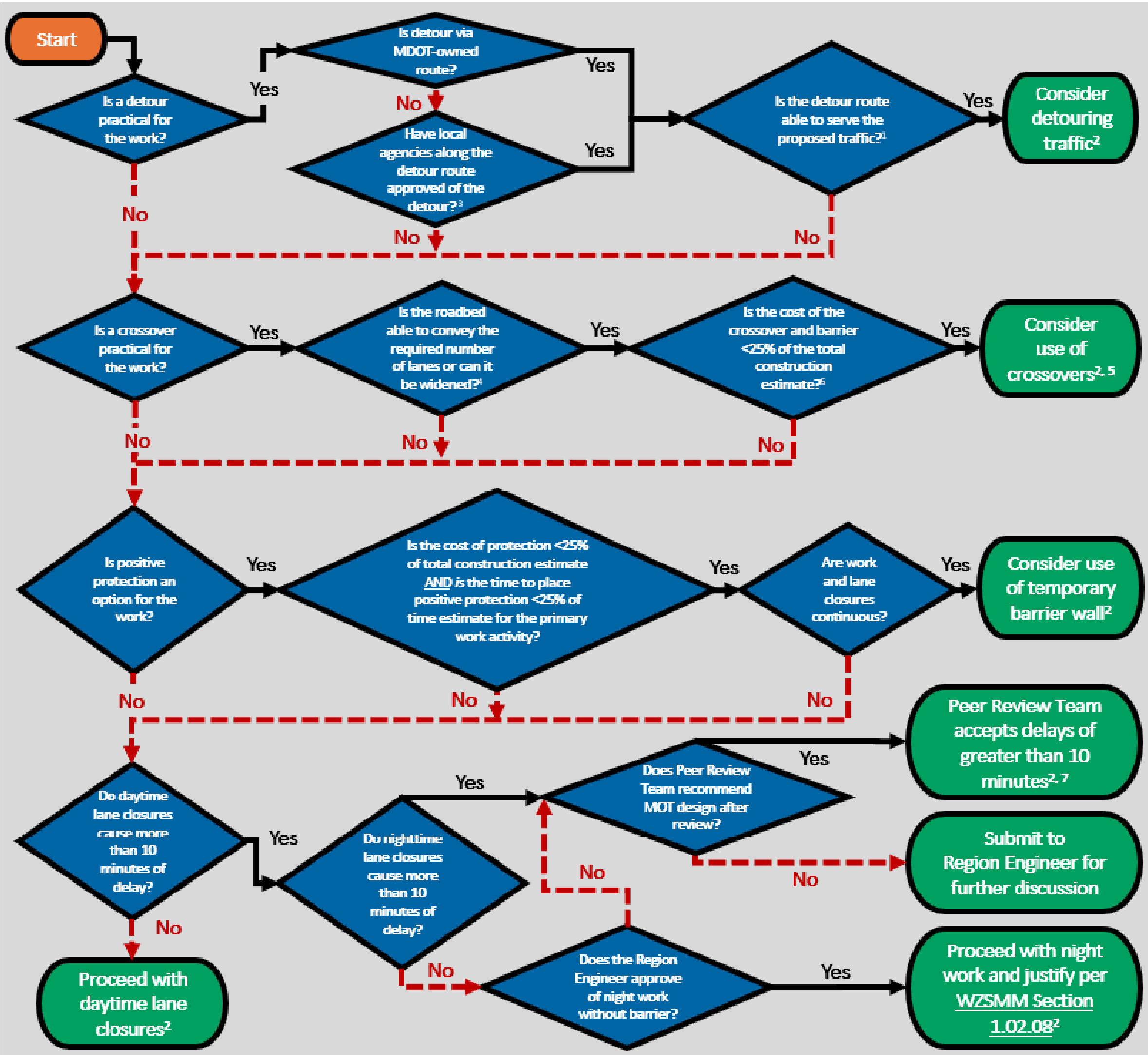
Resource	Recommendation
	performance analyses consistent with **Chapter 4**. This could also include specific training to support the use of the *Microsoft Excel tool*.
MDOT's *Work Zone Safety and Mobility Manual* [6]	Exhibits 2-1, 2-2, 2-3, 2-4, 2-5 identify many of the mitigation strategies discussed in **Chapter 2**. In other words, the manual is largely consistent with the current state of the practice. While AFADs are discussed in Section 6.01.17, consider adding AFADs to Exhibit 2-5. Agencies have also employed wait time display systems that could be considered within Exhibit 2-5.
MDOT's *Work Zone Safety and Mobility Manual* [6]	Section 2.10.07 and Section 2.10.10 of the mobility manual discuss statewide reviews conducted on a regular basis that include changes in crash trends. The findings presented in **Chapters 3-4** can be used to inform this process. Additionally, the concerns related to the reliability of the four work zone UD-10 crash report form fields demonstrated in **Section 4.2.2** should be considered as a part of this process.
MDOT's *Work Zone Safety and Mobility Manual* [6]	Consider updating the statistics at the beginning of Section 4.03.04 of the manual with findings from **Chapter 3-4**.
MDOT's *Work Zone Safety and Mobility Manual* [6]	Part A of Section 6.01.19 of the manual outlines the use of transverse temporary rumble strips for freeways. The department could consider more aggressive use of these devices as a part of freeway projects where lane closures or crossovers are being implemented along facilities without recurring congestion under normal operations (given the relative safety performance impacts for these facilities demonstrated in **Section 4.3**). For example, consider if the three-day (for consideration on any project) and fourteen-day (where they may be required) thresholds could be reduced to maximize the number of days where rumble strips are in place for these types of projects. The *Microsoft Excel tool* could be used to support this process as well as identify poorly performing stages or locations for all types of freeway projects that may benefit from this treatment.
MDOT's *Work Zone Safety and Mobility Manual* [6]	Section 6.06 of the manual discusses the use of ITS devices within Michigan work zones, including guidance for scenarios where such treatments should be considered after a work zone is in place. Findings from **Chapter 4** can be used to expand this guidance, such as considering the use of these devices in scenarios where the SPFs presented in **Figures 56 and 57** suggest diminished safety performance. The *Microsoft Excel tool* can also be used to support this process.
MDOT's *Work Zone Safety and Mobility Manual* [6]	Section 6.06.04 of the manual discusses the use of stopped traffic advisory systems, including the guidance that these systems should be used along corridors with a history of rear end collisions. However, **Section 4.3** provides evidence that freeway facilities that do not experience recurring congestion under normal operations observed the largest relative impacts on safety performance during work operations. Consider revising this guidance to emphasize these systems can be valuable across a broad range of scenarios. The *Microsoft Excel tool* can also be used to support the identification of projects that may benefit from this treatment.
MDOT's *Work Zone Safety and Mobility Manual* [6]	Part B of Section 6.06.09 provides guidance for the use of radar speed trailers, including that more devices can be added at problem areas as defined by the engineer. Consider adding guidance that recommends comparing ongoing safety performance with **Figures 56 and 57 from Section 4.3** to identify potential problem areas. The *Microsoft Excel tool* can also be used to support this process.

Resource	Recommendation
MDOT's *Work Zone Safety and Mobility Manual* [*6*]	Given that House Bills 4132 and 4133 [*279*] authorize MDOT to employ automated speed enforcement systems within highway work zones in Michigan, findings from **Chapter 4** could be used to provide initial guidance for potential projects to consider. The *Microsoft Excel tool* can also be used to support this process.
MDOT's *Work Zone Safety and Mobility Manual* [*6*]	A revised *Safety & Mobility Decision Tree* is provided in **Figure 58** that maintains the existing engineering approach. The revised flowchart provides a structure that should allow for simple modification in the future. One such potential modification could include an additional note specific to the use of crossovers within the flowchart, where the current cost threshold of 25 percent of the total construction cost estimate represents an effective high-level approach for the MDOT. However, an analysis based on findings from **Chapter 4** could be used to determine if there are potential projects where the use of crossovers may represent a particularly effective strategy from a safety perspective compared to other MOT alternatives (such as a lane closure) despite exceeding this threshold. This could be emphasized along facilities without recurring congestion under normal operations (given the relative safety performance effects for these facilities demonstrated in **Section 4.3**). This analysis should incorporate a comprehensive evaluation of the entire construction influence area for each MOT alternative (as opposed to simply comparing performance within the activity area itself). The *Microsoft Excel tool* can also be used to support this process.
All Resources	Future work in this area could include research to develop safety analysis tools (similar to those provided in **Chapter 4)** for non-freeway facilities, with a focus on both trunkline and non-trunkline arterials. This would allow state and local agencies to extend the data-driven methods presented in **Chapter 4** (and the associated *Microsoft Excel tool*) to both arterials and collector roadways. This research would be particularly valuable in that it would allow agencies to develop temporary traffic control plans that maximize mobility and safety performance for non-motorized road users, as well as provide guidance to reduce conflicts between vehicles and traffic regulators.
MDOT's Work Zone Safety *Fast Facts* Page [*269*]	Consider updating the webpage and associated "Work Zones 101" flyer with findings from **Chapter 3**.

MDOT Safety & Mobility Decision Tree

(*Recommended Revisions from OR23-022*)

PA 164 of 2023 describes requirements for closing freeways or portions of freeways. The flowchart below outlines safety considerations to assist in determining maintaining traffic design. Use of the decision tree is mandatory for all MDOT freeway projects and optional for all other roadways. The flowchart is intended to be used to evaluate MOT options and promote a culture of safety for all. It is important to recognize that the decision tree is intended to supplement (and not replace) engineering judgement. Ultimately, the decision tree should help to ensure designers consider overall safety performance, minimize night work, and emphasize the separation of vehicles and workers. Detours should be considered for all stages of the work, not just as a part of the overall project scope.



1	Designers should consider overall traffic volumes, turning movements, coordination of work, and other factors.
2	Designers should consider a range of potential temporary traffic control devices or other work zone mitigation strategies consistent with engineering judgement, including temporary rumble strips, stopped traffic advisories, radar speed trailers, police presence, enhanced night lighting, 25' maximum drum spacing, truck mounted attenuators or mobile truck barriers.
3	Reallocated funds may be offered to Local Agencies to improve detour routes.
4	Designers should consider the number of lanes necessary to maintain less than or equal to 10 minutes of delay.
5	Consider if a zipper wall should be used to accommodate peak hour flow.
6	Designers should consider alternate MOT schemes to accommodate crossovers beyond the conventional temporary barrier wall approach.
7	After assessing all reasonable mitigation measures, the peer review team accepts delays greater than 10 minutes. Mitigation recommendations to be provided by the peer review team.

Figure 58. Recommended MDOT Safety & Mobility Decision Tree

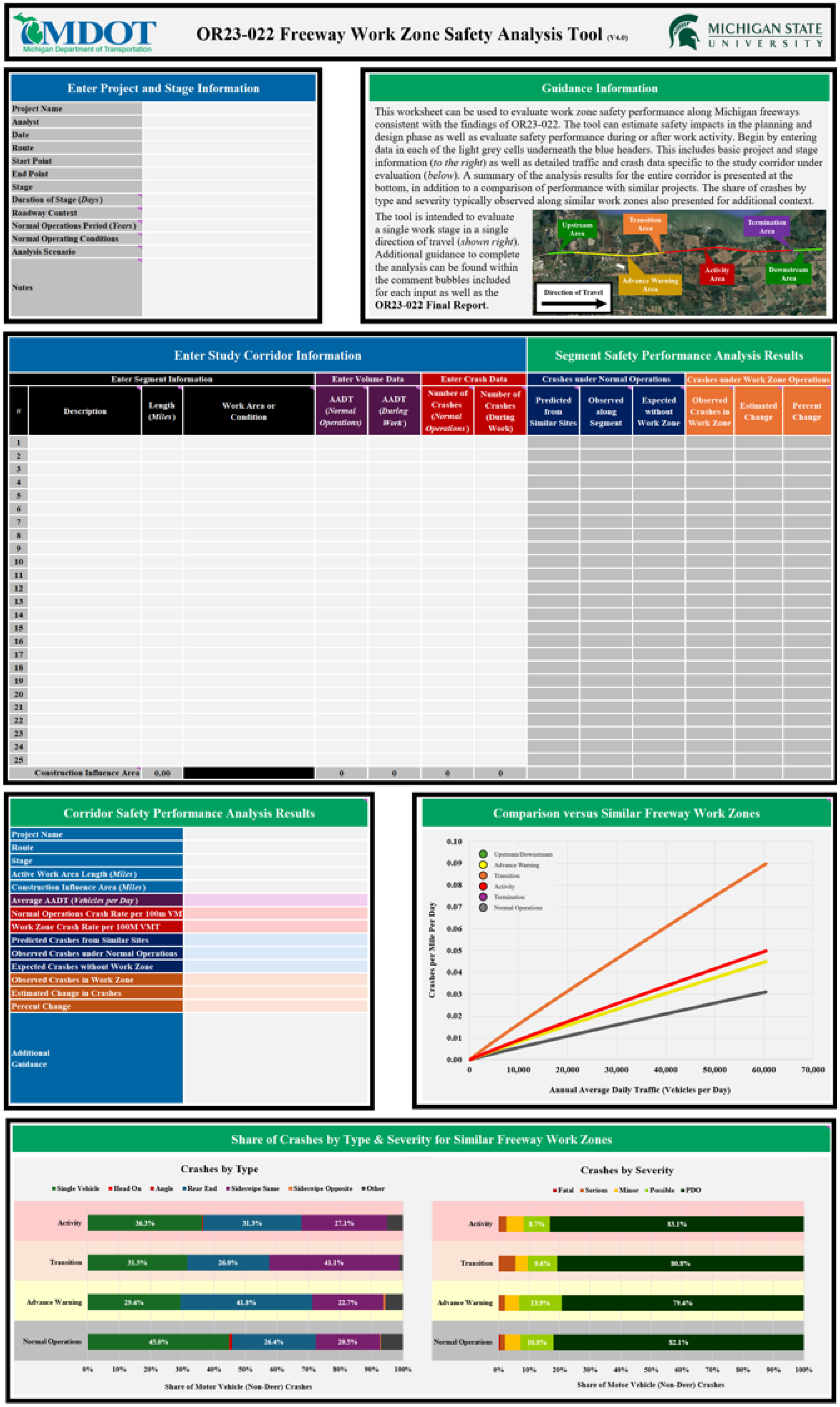


Figure 59. Screenshot of Freeway Work Zone Safety Analysis Tool

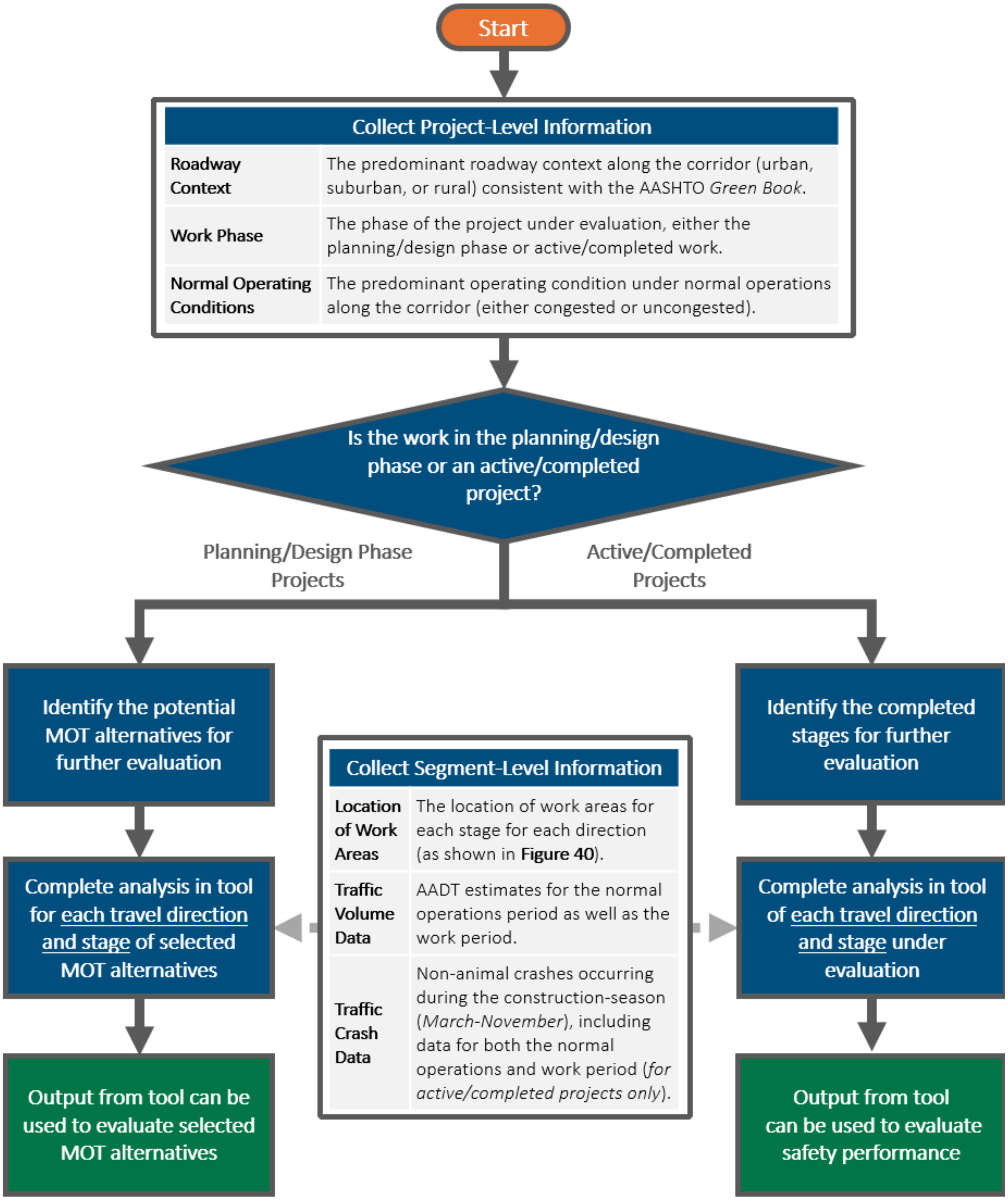


Figure 60. Overview of Freeway Work Zone Safety Analysis Tool Process

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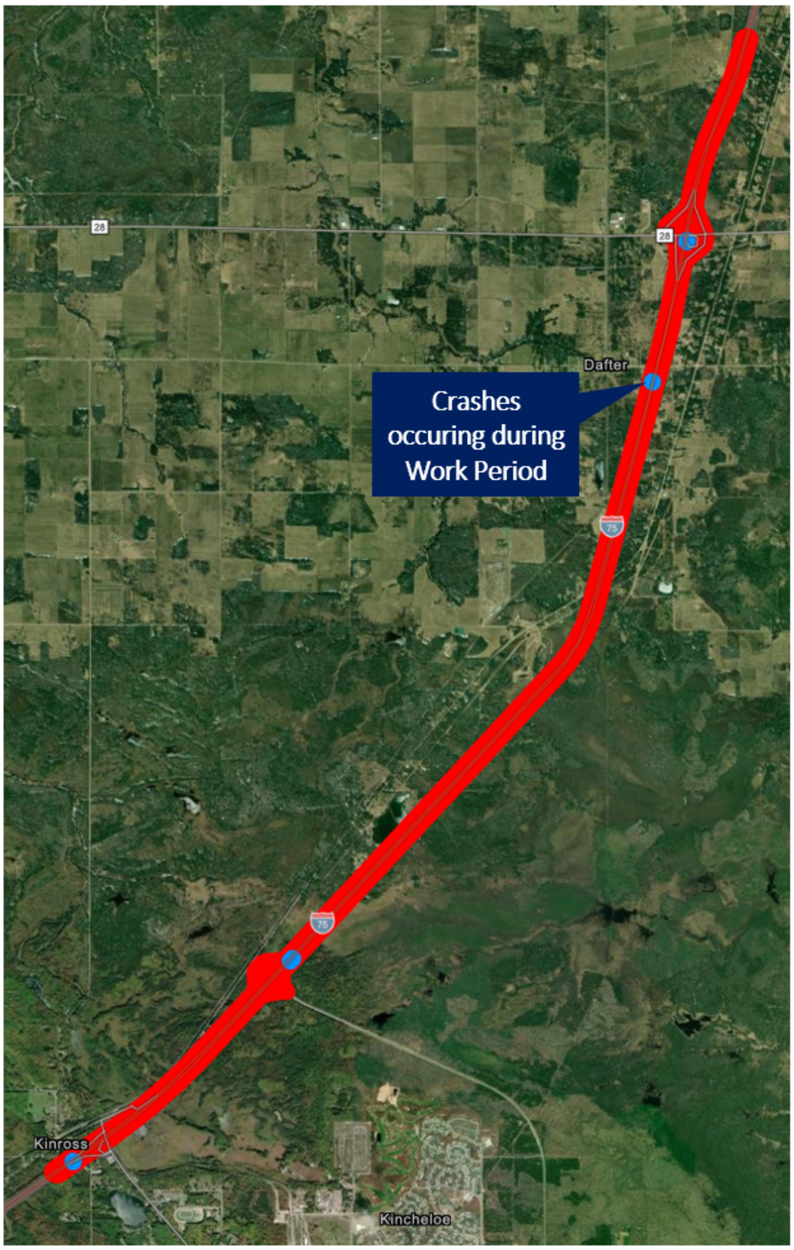
APPENDIX A. PROFILES OF STUDY WORK ZONES

Project profiles specific to each of the 25 freeway work zones evaluated within **Chapter 4** are provided below. For each project, a short narrative is included with the following information:

- An overview of the work as well as a map of the crashes occurring during the work period.
- Next, annual traffic crash and volume data are provided for the study corridor across the entire 2016 to 2023 study period.
    - This includes the identification of periods under normal operations where no work zone was present consistent with the process outlined in **Section 4.2.1**.
- Crash rates observed along the corridor for each stage of the project period are provided, including any winter shutdown periods.
- A comparison between crash rates by worst injury and type experienced during periods where normal operations were present versus active work stages (excluding winter shutdowns).
    - It should be noted that the crash rates by worst injury and type for normal operating conditions is specific to the March to November construction season.
- The estimated change in total crash frequency due to the work activities is provided consistent with the process outlined in **Section 4.3**.
    - This could include summaries by stage, area, or traffic control configuration depending on the project.
- Relevant findings from the analysis of ramp facilities are provided. See section **4.2.3** for more information on freeway ramp facilities.
- Relevant findings from the review of UD-10 crash report forms are provided as outlined in **Section 4.1.3.1**.

A.1 Resurfacing Project along I-75 (M-80 to M-28)

The rural freeway project shown in the map below included approximately 8.3 miles of resurfacing along I-75 in Chippewa County. This work was completed in three stages during the 2021 construction season via a series of single lane closures both with and without the use of temporary concrete barrier. It should also be noted that there were limitations in identifying the location of specific temporary traffic control devices. This primarily impacted the ability to determine the location of advance warning, transition and termination areas for this project.



Map of I-75 (M-80 to M-28) Resurfacing Project

Aside from the COVID-19 pandemic, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2021. Therefore, data from 2016-2019 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: I-75 (M-80 to M-28)

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	2,804	2,857	22,143,659	16	3	0	0.0%	72.3	13.5	0.0
2017	2,804	2,857	22,083,157	15	2	0	0.0%	67.9	9.1	0.0
2018	2,804	2,857	22,083,157	18	5	0	0.0%	81.5	22.6	0.0
2019	2,804	2,857	22,083,157	18	2	0	0.0%	81.5	9.1	0.0
2020	2,480	2,527	19,579,177	17	3	0	0.0%	86.8	15.3	0.0
2021	2,827	2,881	22,309,162	24	6	5	20.8%	107.6	26.9	22.4
2022	3,193	3,147	24,853,009	24	4	0	0.0%	96.6	16.1	0.0
2023	3,339	3,290	26,043,067	19	3	0	0.0%	73.0	11.5	0.0
All Years	**2,882**	**2,909**	**181,177,546**	**151**	**28**	**5**	**3.3%**	**83.3**	**15.5**	**2.8**

While the crash rate along the corridor was lower during the active work period (69.0) than is observed during a typical year without construction activity (75.8 for the years 2016 to 2019), it is critical to recognize that this work occurred over a single construction season without a winter shutdown where higher rates of single vehicle collisions are typically observed. The crash rate observed during a typical construction-season along this corridor is considerably lower (43.7), suggesting substantially diminished safety performance during the work period driven by an increase in the rate of sideswipe same collisions.

Summary of Work Zone Traffic Crash and Volume Data: I-75 (M-80 to M-28)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Joint Repairs	5/10/2021	5/31/2021	22	Single Lane Closures	1,344,662	1	0	1	100.0%	74.4	0.0	74.4
Pre-Stage	6/1/2021	6/14/2021	14	Single Lane Closures	855,694	0	0	0		0.0	0.0	0.0
Stage 1a	6/15/2021	7/9/2021	25	Single Lane Closures with Barrier	1,528,025	0	0	0		0.0	0.0	0.0
Stage 1b	7/10/2021	8/2/2021	24	Single Lane Closures with Barrier	1,466,904	1	0	0	0.0%	68.2	0.0	0.0
Stages 2/3	8/3/2021	10/22/2021	81	Single Lane Closures	4,950,800	5	1	4	80.0%	101.0	20.2	80.8
All Stages	**5/10/2021**	**10/22/2021**	**166**		**10,146,085**	**7**	**1**	**5**	**71.4%**	**69.0**	**9.9**	**49.3**

Traffic Crash Rates by Worst Injury and Type: I-75 (M-80 to M-28)

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.0	0.0
Severe Injury (A)	3.0	0.0
Minor Injury (B)	3.0	9.9
Possible Injury (C)	3.0	0.0
Property Damge Only	34.7	59.1
Total	**43.7**	**69.0**

Crash Type	Normal Operations	All Stages
Single Vehicle	33.2	29.6
Head On	0.0	0.0
Angle	0.0	0.0
Rear End	7.5	0.0
Sideswipe Same	1.5	39.4
Sideswipe Opposite	0.0	0.0
Other	1.5	0.0
Total	**43.7**	**69.0**

Overall, approximately 3.3 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations, which represents an increase of approximately 86.8 percent. The worst performance was observed during Stages 2 and 3, as well as when a conventional left lane closure was in place.

Total Traffic Crashes by Stage: I-75 (M-80 to M-28)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Joint Repairs	Single Lane Closures	5/10/2021	5/31/2021	22	0.5	0.6	0.5	1.0	+0.5	101.4%
Pre-Stage	Single Lane Closures	6/1/2021	6/14/2021	14	0.3	0.4	0.3	0.0	-0.3	-100.0%
Stage 1a	Single Lane Closures with Barrier	6/15/2021	7/9/2021	25	0.5	0.7	0.6	0.0	-0.6	-100.0%
Stage 1b	Single Lane Closures with Barrier	7/10/2021	8/2/2021	24	0.5	0.6	0.5	1.0	+0.5	84.6%
Stages 2/3	Single Lane Closures	8/3/2021	10/22/2021	81	1.7	2.2	1.8	5.0	+3.2	173.5%
All Stages		**5/10/2021**	**10/22/2021**	**166**	**3.5**	**4.4**	**3.7**	**7.0**	**+3.3**	**86.8%**

Total Traffic Crashes by Type of Activity: I-75 (M-80 to M-28)

Type of Activity	VMT	Crashes during Normal Operations			Crashes during Work Zone Operations		
		Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Single Lane Closure (Right)	2,438,111	0.9	1.1	0.9	2.0	+1.1	118.4%
Single Lane Closure (Left)	2,650,253	0.9	1.3	1.0	4.0	+3.0	293.9%
Single Lane Closure (Right) with Shift and Barrier	1,223,164	0.4	0.6	0.5	0.0	-0.5	-100.0%
Single Lane Closure (Left) with Shift and Barrier	1,174,238	0.4	0.6	0.4	0.0	-0.4	-100.0%

There were no traffic crashes occurring along ramps impacted by the work activity during the construction period. It should be noted that crashes are also generally rare along these relatively low-volume ramps under normal conditions.

Traffic Crashes by Ramp: I-75 (M-80 to M-28)

Ramp Information			Average	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.	AADT	Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
NB Exit Ramp to Gaines Hwy	0.326	NB	68	1,461	0	0	166	0	0	0.000	0.000
Gaines Hwy NB Entrance Ramp	0.283	NB	844	1,461	3	0	166	0	0	0.002	0.000
NB Exit Ramp to M-28	0.406	NB	489	1,461	4	1	166	0	0	0.003	0.000
EB M-28 NB Entrance Ramp	0.242	NB	967	1,461	1	0	166	0	0	0.001	0.000
WB M-28 NB Entrance Ramp	0.320	NB	248	1,461	1	0	166	0	0	0.001	0.000
SB Exit Ramp to M-28	0.387	SB	1,259	1,461	4	0	166	0	0	0.003	0.000
M-28 SB Entrance Ramp	0.329	SB	656	1,461	0	0	166	0	0	0.000	0.000
SB Exit Ramp to Gaines Hwy	0.318	SB	720	1,461	1	0	166	0	0	0.001	0.000
Gaines Hwy SB Entrance Ramp	0.332	SB	77	1,461	0	0	166	0	0	0.000	0.000
All Ramps	**2.944**	**-**	**592**	**13,149**	**14**	**1**	**1,494**	**0**	**0**	**0.001**	**0.000**

A.2 Resurfacing Project along US-127 (M-55 to Muskegon River Bridge)

The rural freeway project shown in the map below included approximately 5.3 miles of resurfacing work along US-127 as it runs west of Houghton Lake in Roscommon County. The work was completed in five stages via single lane closures during the 2020 construction season. A double step down approach was used (75 mph → 70 mph → 60 mph) to accommodate the work zone speed limit. It should also be noted that there were limitations in identifying the timing of specific stages and associated temporary traffic control configurations. This primarily impacted the ability to determine (1) when either the left or right lane closure was in place and (2) the location of advance warning, transition and termination areas.

Map of US-127 (M-55 to Muskegon River Bridge) Resurfacing Project

The rate of crashes was elevated during the 2020 construction season as compared to the period that was considered as normal operations (2018 to 2019) from a work zone perspective.

Summary of Traffic Crash and Volume Data: US-127 (M-55 to Muskegon River Bridge)

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	4,013	4,137	24,428,291	14	3	0	0.0%	57.3	12.3	0.0
2017	4,013	4,137	24,361,547	16	2	0	0.0%	65.7	8.2	0.0
2018	4,046	4,171	24,575,102	11	4	0	0.0%	44.8	16.3	0.0
2019	4,040	4,167	24,383,316	12	3	0	0.0%	49.2	12.3	0.0
2020	3,510	4,169	22,401,457	17	6	6	35.3%	75.9	26.8	26.8
2021	3,981	4,722	25,487,534	19	3	0	0.0%	74.5	11.8	0.0
2022	3,853	4,570	24,717,543	13	4	0	0.0%	52.6	16.2	0.0
2023	4,779	5,268	29,889,402	9	1	0	0.0%	30.1	3.3	0.0
All Years	**4,030**	**4,417**	**200,244,193**	**111**	**26**	**6**	**5.4%**	**55.4**	**13.0**	**3.0**

Traffic crash rates were considerably higher during the work period (88.4) than what is typically observed during a typical year with no construction activity (47.0 for the years 2018 to 2019). It is critical to recognize that this work occurred over a single construction season without a winter shutdown where higher rates of single vehicle collisions are typically observed. The crash rate observed during a typical construction-season along this corridor is considerably lower (32.7), suggesting substantially diminished safety performance during the work period driven by an increase in the rate of single vehicle and rear end collisions.

Summary of Work Zone Crash/Volume Data: US-127 (M-55 to Muskegon River Bridge)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Stages 1-5	4/20/2020	10/2/2020	166	Single Lane Closures	10,182,666	9	3	5	55.6%	88.4	29.5	49.1
All Stages	**4/20/2020**	**10/2/2020**	**166**		**10,182,666**	**9**	**3**	**5**	**55.6%**	**88.4**	**29.5**	**49.1**

Traffic Crash Rates by Worst Injury and Type: US-127 (M-55 to Muskegon River Bridge)

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.0	0.0
Severe Injury (A)	0.0	0.0
Minor Injury (B)	2.7	9.8
Possible Injury (C)	2.7	19.6
Property Damge Only	27.2	58.9
Total	**32.7**	**88.4**

Crash Type	Normal Operations	All Stages
Single Vehicle	19.1	68.7
Head On	0.0	0.0
Angle	0.0	0.0
Rear End	5.4	19.6
Sideswipe Same	2.7	0.0
Sideswipe Opposite	0.0	0.0
Other	5.4	0.0
Total	**32.7**	**88.4**

Overall, approximately 5.5 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations. This represents an increase of approximately 156.8 percent. This was primarily driven by collisions occurring within the activity area along northbound US-127.

Total Traffic Crashes by Stage: US-127 (M-55 to Muskegon River Bridge)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Stages 1-5	Single Lane Closures	4/20/2020	10/2/2020	166	3.5	3.6	3.5	9.0	+5.5	156.8%
All Stages		4/20/2020	10/2/2020	166	3.5	3.6	3.5	9.0	+5.5	156.8%

Total Traffic Crashes by Area: US-127 (M-55 to Muskegon River Bridge)

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
US-127 NB	Upstream	3,857	0.3	0.7	0.3	0.0	-0.3	-100.0%
	Activity	4,377	1.3	1.2	1.3	6.0	+4.7	367.1%
	Downstream	4,377	0.3	0.0	0.2	1.0	+0.8	315.0%
All Northbound Areas		4,204	1.9	1.9	1.9	7.0	+5.1	276.6%
US-127 SB	Upstream	3,912	0.3	0.3	0.3	0.0	-0.3	-100.0%
	Activity	3,912	1.2	1.1	1.2	2.0	+0.8	71.6%
	Downstream	2,907	0.2	0.3	0.2	0.0	-0.2	-100.0%
All Soundbound Areas		3,577	1.6	1.7	1.6	2.0	+0.4	21.5%

In general, there were not major changes in safety performance along the ramps impacted by the work activity. However, the southbound exit ramp to westbound M-55 experienced three collisions that were not related to work activity within the work period.

Traffic Crashes by Ramp: US-127 (M-55 to Muskegon River Bridge)

Ramp Information			Average AADT	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.		Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
NB Exit Ramp to M-55	0.326	NB	807	730	1	0	166	0	0	0.001	0.000
M-55 Entrance Ramp to NB US-127	0.351	NB	1,848	730	1	0	166	0	0	0.001	0.000
SB Exit Ramp to WB M-55	0.316	SB	1,167	730	1	0	166	3	0	0.001	0.018
WB M-55 Entrance Ramp to SB US-127	0.230	SB	567	730	1	0	166	0	0	0.001	0.000
SB Exit Ramp to EB M-55	0.224	SB	633	730	1	0	166	0	0	0.001	0.000
EB M-55 Entrance Ramp to SB US-127	0.288	SB	276	730	0	0	166	0	0	0.000	0.000
All Ramps	1.736	-	883	4,380	5	0	996	3	0	0.001	0.003

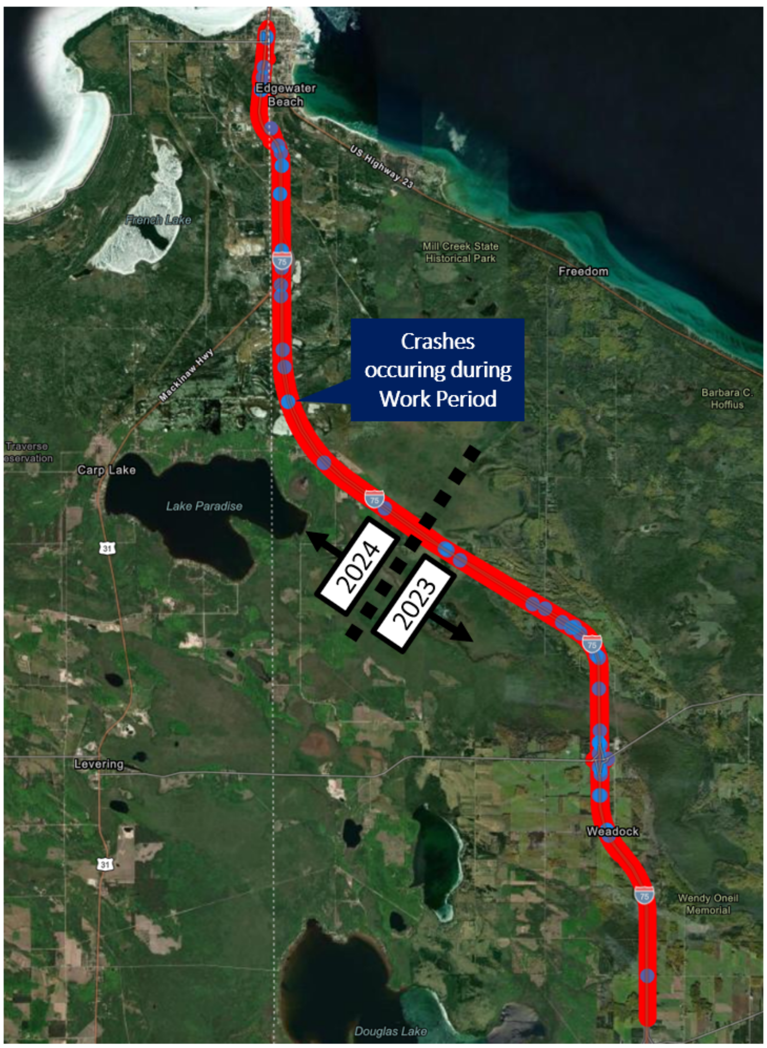
Given the review of each UD-10 crash report form diagram and narrative, 6 of the 12 collisions occurring during the work period were directly related to work zone temporary traffic control. Most importantly, this included three incidents where vehicles entered the work area along northbound US-127.

Work Zone Traffic Crashes by Circumstance: US-127 (M-55 to Muskegon River Bridge)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	0	0.0%
	Vehicle(s) Struck Channelizing Devices	0	0.0%
	Sideswipe Same Collisions Related to Lane Closure	0	0.0%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	1	8.3%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	1	8.3%
	Vehicle(s) Entered Work Area	3	25.0%
	Collisions involving Work Vehicles	0	0.0%
	Collisions involving Workers	0	0.0%
	Other Work Zone Related Motor Vehicle Crashes	1	8.3%
	All Motor Vehicle Crashes Directly Related to Work Zone	**6**	**50.0%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	2	16.7%
	Other Sideswipe Same Collisions	1	8.3%
	Other Rear End Collisions	2	16.7%
	Rear End Collisions at Ramp Termini	1	8.3%
	Vehicles Striking Loose Objects on Roadway	0	0.0%
	Vehicles Struck Pedestrian on Freeway	0	0.0%
	Vehicles Struck Pedestrian at Ramp Termini	0	0.0%
	Vehicles Struck Bicyclist at Ramp Termini	0	0.0%
	Other Motor Vehicle Crashes	0	0.0%
	All Other Motor Vehicle Crashes	**6**	**50.0%**
	Total	**12**	**100.0%**

A.3 Reconstruction Project along I-75 (Levering Road to US-31)

The rural freeway project shown in the map below included approximately 10 miles of reconstruction work along I-75 south of the Mackinac Bridge. While initial stages began in 2022, the majority of the work was completed with moveable barrier walls across two segments; where the southern half of the project was completed in 2023, and the northern half of the project was completed in 2024. Data for the entire project area was collected; however, it should be noted that the northern half of the corridor was not evaluated given that this falls outside of the 2016 to 2023 study period. Additionally, there were limitations in identifying the timing of specific stages and associated temporary traffic control configurations. This primarily impacted the ability to determine (1) details of the mobile barrier configuration beyond the number of lanes and (2) the location of transition and termination areas.



Map of I-75 (Levering Road to US-31) Reconstruction Project

Aside from the COVID-19 pandemic, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2022. Therefore, data from 2017-2019 and 2021 were considered to be under normal operations from a work zone perspective (excluding data from 2016 to minimize the impact of the speed limit change).

Summary of Traffic Crash and Volume Data: I-75 (Levering Road to US-31)

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	7,507	6,858	73,150,349	19	5	1	5.3%	26.0	6.8	1.4
2017	7,507	6,858	72,950,484	21	7	0	0.0%	28.8	9.6	0.0
2018	7,564	6,920	73,586,830	22	7	0	0.0%	29.9	9.5	0.0
2019	7,487	6,379	71,421,995	17	4	0	0.0%	23.8	5.6	0.0
2020	4,799	4,001	46,527,895	18	6	1	5.6%	38.7	12.9	2.1
2021	5,500	4,585	53,173,162	23	4	0	0.0%	43.3	7.5	0.0
2022	5,340	4,452	51,632,050	29	6	1	3.4%	56.2	11.6	1.9
2023	5,253	3,664	44,182,515	27	3	8	29.6%	61.1	6.8	18.1
All Years	**6,370**	**5,465**	**486,625,280**	**176**	**42**	**11**	**6.3%**	**36.2**	**8.6**	**2.3**

Traffic crash rates were considerably higher during the work period (50.3) than what is typically observed during a typical year with no construction activity (30.6 for the years 2017 to 2019 and 2021). It is critical to recognize that this includes the entire corridor (where work was focused only in the southern section during the study period).

Summary of Work Zone Traffic Crash and Volume Data: I-75 (Levering Road to US-31)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Pre-Stage	6/11/2022	9/30/2022	112	Pre-Stage Work	15,843,259	4	2	0	0.0%	25.2	12.6	0.0
Stage 1	10/1/2022	11/15/2022	46	Intermittent Lane/Shoulder Closures	6,507,053	2	1	0	0.0%	30.7	15.4	0.0
Winter 2022-2023	11/16/2022	4/9/2023	145	All Lanes Open	19,032,066	10	0	0	0.0%	52.5	0.0	0.0
Stages 2-3	4/10/2023	10/27/2023	201	Moveable Barrier Wall	24,332,626	16	2	8	50.0%	65.8	8.2	32.9
Winter 2023-2024	10/28/2023	12/31/2023	65	All Lanes Open	7,862,919	5	1	0	0.0%	63.6	12.7	0.0
All Stages	**6/11/2022**	**12/31/2023**	**569**		**73,577,923**	**37**	**6**	**8**	**21.6%**	**50.3**	**8.2**	**10.9**

Crash Rates by Worst Injury/Type: I-75 (Levering Rd. to US-31) - *Excludes Winter Shutdown*

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.0	0.0
Severe Injury (A)	0.0	0.0
Minor Injury (B)	4.9	2.1
Possible Injury (C)	1.5	8.6
Property Damge Only	17.2	36.4
Total	**23.6**	**47.1**

Crash Type	Normal Operations	All Stages
Single Vehicle	21.1	34.3
Head On	0.0	0.0
Angle	0.0	0.0
Rear End	1.5	4.3
Sideswipe Same	1.0	8.6
Sideswipe Opposite	0.0	0.0
Other	0.0	0.0
Total	**23.6**	**47.1**

Overall, approximately 1.9 additional traffic crashes are estimated to have occurred across the entire corridor (including the northern section that was constructed in 2024) during the study work period than would have been expected under normal operations. While there was not a major overall impact across the entire work period (5.3 percent), there was an increase in collisions within the northbound advance warning area and southbound activity area while the movable barrier was in place. It can also be observed that the northern section of the corridor (which was under normal operations during the work period) experienced safety performance that was generally consistent with what is observed during the years before the construction work. Ultimately, approximately 1.9 additional crashes are estimated to have occurred across the southern section of the corridor, representing a 5.3 percent increase over normal operations. In general, there were not major changes in safety performance observed along the ramps impacted by the work activity.

Total Traffic Crashes by Stage: I-75 (Levering Road to US-31)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Pre-Stage	Pre-Stage Work	6/11/2022	9/30/2022	112	5.4	3.6	4.8	4.0	-0.8	-16.3%
Stage 1	Intermittent Lane/Shoulder Closures	10/1/2022	11/15/2022	46	2.2	1.5	2.0	2.0	+0.0	1.9%
Winter 2022-2023	All Lanes Open	11/16/2022	4/9/2023	145	17.3	9.4	14.8	10.0	-4.8	-32.4%
Stages 2-3	Moveable Barrier Wall	4/10/2023	10/27/2023	201	8.3	5.4	7.3	16.0	+8.7	117.8%
Winter 2023-2024	All Lanes Open	10/28/2023	12/31/2023	65	7.3	3.8	6.3	5.0	-1.3	-20.1%
All Stages		6/11/2022	12/31/2023	569	40.6	23.7	35.1	37.0	+1.9	5.3%

Total Traffic Crashes by Area: I-75 (Levering Rd. to US-31) – *Excludes Winter Shutdown*

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
I-75 NB	Upstream	3,244	0.8	0.2	0.6	1.0	+0.4	59.8%
	Advance Warning	3,173	0.5	0.0	0.4	3.0	+2.6	750.6%
	Activity	4,827	4.3	4.3	4.3	6.0	+1.7	41.1%
	Downstream	4,618	2.0	2.1	2.0	2.0	-0.0	-2.4%
All Northbound Areas		3,966	7.5	6.5	7.3	12.0	+4.7	64.8%
I-75 SB	Upstream	6,008	3.0	1.5	2.4	2.0	-0.4	-17.6%
	Advance Warning	4,604	0.7	0.4	0.6	0.0	-0.6	-100.0%
	Activity	4,981	4.3	1.6	3.3	8.0	+4.7	140.1%
	Downstream	3,551	0.4	0.6	0.5	0.0	-0.5	-100.0%
All Soundbound Areas		4,786	8.4	4.0	6.8	10.0	+3.2	46.9%

Traffic Crashes by Traffic Control in Activity Area: I-75 (Levering Road to US-31)

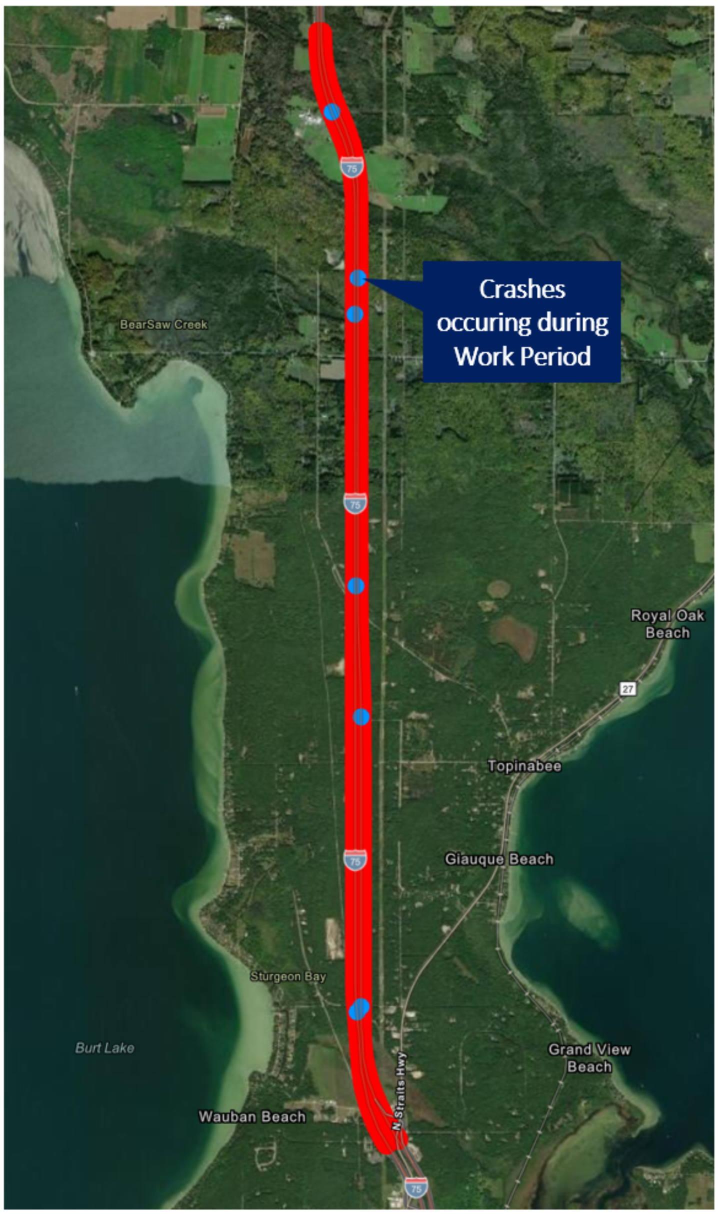
Type of Activity	VMT	Crashes during Normal Operations			Crashes during Work Zone Operations		
		Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Pre-Stage Work	11,868,534	4.0	2.7	3.6	2.0	-1.6	-43.9%
Intermittent Lane and Shoulder Closures	4,874,576	1.7	1.1	1.5	2.0	+0.5	36.7%
2+1 Lane Closure with Movable Barrier	8,283,228	2.8	2.0	2.6	10.0	+7.4	290.9%

Traffic Crashes by Ramp: I-75 (Levering Road to US-31)

Ramp Information			Average AADT	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.		Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
NB Exit Ramp to Levering Road	0.206	NB	459	1,460	2	0	569	1	0	0.001	0.002
Levering Road NB Entrance Ramp	0.200	NB	186	1,460	1	0	569	0	0	0.001	0.000
SB Exit Ramp to Levering Road	0.162	SB	177	1,460	1	0	569	1	0	0.001	0.002
Levering Road SB Entrance Ramp	0.241	SB	477	1,460	0	0	569	0	0	0.000	0.000
All Ramps	0.808	-	325	5,840	4	0	2,276	2	0	0.001	0.001

A.4 Resurfacing Project along Southbound I-75 (M-27 to Topinabee Mail Route)

The rural freeway project shown in the map below included approximately 2.3 miles of resurfacing and reconstruction work along Southbound I-75 in Cheboygan County. The work was completed via single lane closures during the 2020 construction season. It should also be noted that there were limitations in identifying the timing of specific stages and associated temporary traffic control configurations. This primarily impacted the ability to determine when the left or right lane was closed. There were no ramps present within the work area and the project also included considerable tree clearing along both sides of the corridor.



Map of I-75 (M-27 to Topinabee Mail Route) Resurfacing Project

Traffic crash and volume data along the corridor were relatively consistent prior to the implementation of work zone temporary traffic control in 2020. Therefore, the period from 2016 to 2019 was considered to be normal operations from a work zone perspective. It is worth noting that collisions decreased along the corridor in the post-construction period, where the significant tree trimming effort may have represented an effective safety treatment.

Summary of Traffic Crash Volume Data: I-75 (M-27 to Topinabee Mail Route) Project

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	6,930	5,825	32,176,818	15	2	1	6.7%	46.6	6.2	3.1
2017	6,930	5,825	32,088,903	18	4	0	0.0%	56.1	12.5	0.0
2018	6,992	5,877	32,375,703	10	2	0	0.0%	30.9	6.2	0.0
2019	6,908	5,806	31,985,756	13	2	0	0.0%	40.6	6.3	0.0
2020	6,107	5,133	28,354,954	11	3	1	9.1%	38.8	10.6	3.5
2021	5,410	4,575	25,120,165	5	1	0	0.0%	19.9	4.0	0.0
2022	5,253	4,442	24,390,586	5	1	0	0.0%	20.5	4.1	0.0
2023	4,843	4,669	23,930,196	4	1	0	0.0%	16.7	4.2	0.0
All Years	**6,172**	**5,269**	**230,423,081**	**81**	**16**	**2**	**2.5%**	**35.2**	**6.9**	**0.9**

Traffic crash rates during the work period across the entire corridor (39.5) were similar to what is typically observed during a typical year with no construction activity (43.5 for the years 2016 to 2019). The crash rate observed during a typical construction-season along this corridor is considerably lower (25.9), where the rate of single vehicle crashes was elevated during the work period.

Summary of WZ Traffic Crash/Volume Data: I-75 (M-27 to Topinabee Mail Route) Project

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Stage 1	3/2/2020	4/14/2020	44	Tree Clearing	3,409,002	1	0	1	100.0%	29.3	0.0	29.3
Stages 2-5	4/15/2020	6/12/2020	59	Single Lane Closures	4,571,162	1	0	0	0.0%	21.9	0.0	0.0
Stage 6	6/13/2020	10/16/2020	126	Tree Clearing	9,762,142	5	0	0	0.0%	51.2	0.0	0.0
All Stages	**3/2/2020**	**10/16/2020**	**229**		**17,742,306**	**7**	**0**	**1**	**14.3%**	**39.5**	**0.0**	**5.6**

Crash Rates by Worst Injury and Type: I-75 (M-27 to Topinabee Mail Route) Project

Worst Injury in Crash	Normal Operations	All Stages
Fatal	1.0	0.0
Severe Injury (A)	0.0	0.0
Minor Injury (B)	6.2	0.0
Possible Injury (C)	1.0	0.0
Property Damge Only	17.6	39.5
Total	**25.9**	**39.5**

Crash Type	Normal Operations	All Stages
Single Vehicle	19.7	33.8
Head On	0.0	0.0
Angle	0.0	0.0
Rear End	2.1	0.0
Sideswipe Same	3.1	5.6
Sideswipe Opposite	0.0	0.0
Other	1.0	0.0
Total	**25.9**	**39.5**

Overall, approximately 1.5 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations. However, focusing along the southbound direction where work activity was present, a total of 1.2 additional traffic crashes are estimated to have occurred (representing an increase of 40.9 percent).

Total Traffic Crashes by Stage: I-75 (M-27 to Topinabee Mail Route) Project

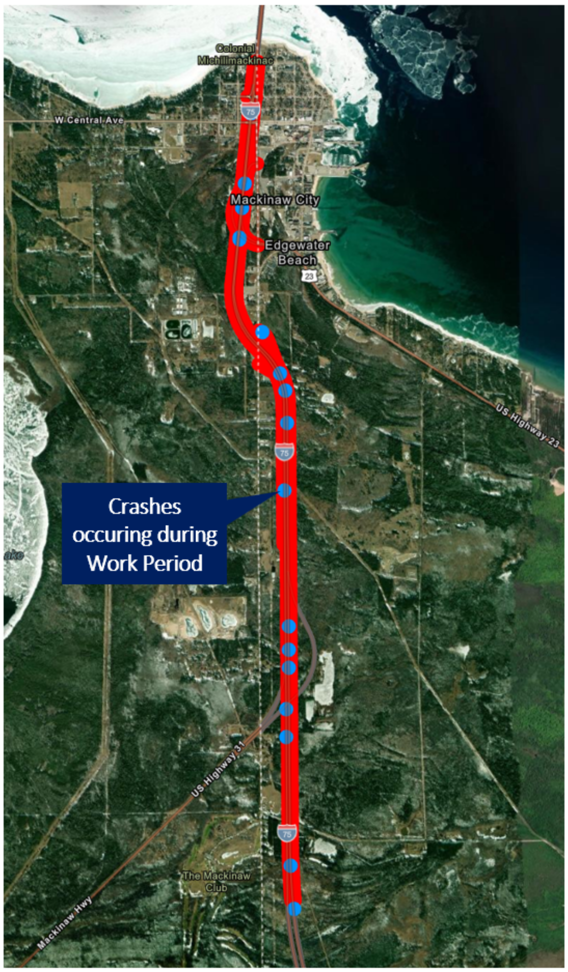
Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Stage 1	Tree Clearing	3/2/2020	4/14/2020	44	1.2	0.9	1.0	1.0	-0.0	-4.7%
Stages 2-5	Single Lane Closures	4/15/2020	6/12/2020	59	1.5	1.2	1.4	1.0	-0.4	-28.9%
Stage 6	Tree Clearing	6/13/2020	10/16/2020	126	3.3	2.5	3.0	5.0	+2.0	66.4%
All Stages		3/2/2020	10/16/2020	229	6.0	4.6	5.5	7.0	+1.5	28.2%

Total Traffic Crashes by Area: I-75 (M-27 to Topinabee Mail Route) Project

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
I-75 NB	Upstream	5,133	0.4	0.7	0.5	1.0	+0.5	93.7%
	Activity	5,133	1.1	0.2	0.8	1.0	+0.2	32.5%
	Downstream	5,133	1.3	1.5	1.4	1.0	-0.4	-26.0%
All Northbound Areas		5,133	2.7	2.4	2.6	3.0	+0.4	14.4%
I-75 SB	Upstream	6,107	1.2	1.0	1.1	2.0	+0.9	76.6%
	Advance Warning	6,107	0.3	0.3	0.3	0.0	-0.3	-100.0%
	Transition	6,107	0.0	0.0	0.0	0.0	-0.0	-100.0%
	Activity	6,107	1.3	0.3	0.9	1.0	+0.1	11.5%
	Termination	6,107	0.0	0.0	0.0	0.0	-0.0	-100.0%
	Downstream	6,107	0.5	0.6	0.5	1.0	+0.5	99.4%
All Soundbound Areas		6,107	3.2	2.2	2.8	4.0	+1.2	40.9%

A.5 Reconstruction and Resurfacing along I-75 (Old M-108 to Mackinac Bridge)

The rural freeway project shown in the map below included approximately 2.0 miles of resurfacing and reconstruction work along I-75 south of the Mackinac Bridge. The work was completed via single lane closures during the 2022 construction season. It should be noted there were also two 3-day periods with full closures. Additionally, there were limitations in identifying the timing of specific stages and associated temporary traffic control configurations. This primarily impacted the ability to determine (1) when either the left or right lane closure was in place and (2) the location of transition and termination areas.



Map of I-75 (Old M-108 to Mackinac Bridge) Reconstruction/Resurfacing Project

Aside from the COVID-19 pandemic, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2022. Therefore, data from 2017-2019 and 2021 were considered to be under normal operations from a work zone perspective (excluding data from 2016 to minimize the impact of the speed limit change).

Summary of Traffic Crash and Volume Data: I-75 (Old M-108 to Mackinac Bridge)

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	7,572	7,326	20,716,947	8	1	1	12.5%	38.6	4.8	4.8
2017	7,572	7,326	20,660,343	7	2	1	14.3%	33.9	9.7	4.8
2018	7,623	7,371	20,780,852	10	3	0	0.0%	48.1	14.4	0.0
2019	7,555	7,311	20,619,492	9	2	3	33.3%	43.6	9.7	14.5
2020	5,548	5,823	16,279,164	8	1	1	12.5%	49.1	6.1	6.1
2021	6,358	6,674	18,605,572	9	3	0	0.0%	48.4	16.1	0.0
2022	6,174	6,480	18,065,434	17	3	6	35.3%	94.1	16.6	33.2
2023	6,331	6,606	18,378,119	8	3	1	12.5%	43.5	16.3	5.4
All Years	**6,842**	**6,865**	**154,105,923**	**76**	**18**	**13**	**17.1%**	**49.3**	**11.7**	**8.4**

Traffic crash rates were considerably higher during the work period (104.0) than what is typically observed during a typical year with no construction activity (43.4 for the years 2017 to 2019 and 2021). The crash rate observed during a typical construction-season along this corridor is similar (43.0) to the annual performance. The increase in crash rate was driven primarily by an increase in sideswipe same collisions during the work period.

Summary of Work Zone Traffic Crash and Volume Data: I-75 (Old M-108 to Mackinac Bridge)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Tree Clearing and Pre-Work	3/7/2022	4/10/2022	35	Tree Clearing	1,732,302	2	0	0	0.0%	115.5	0.0	0.0
2022 Construction Season	4/11/2022	10/28/2022	201	Single Lane Closures	9,803,886	10	2	5	50.0%	102.0	20.4	51.0
All Stages	**3/7/2022**	**10/28/2022**	**236**		**11,536,188**	**12**	**2**	**5**	**41.7%**	**104.0**	**17.3**	**43.3**

Traffic Crash Rates by Worst Injury and Type: I-75 (Old M-108 to Mackinac Bridge)

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.0	0.0
Severe Injury (A)	3.3	0.0
Minor Injury (B)	5.0	0.0
Possible Injury (C)	3.3	17.3
Property Damge Only	31.4	86.7
Total	**43.0**	**104.0**

Crash Type	Normal Operations	All Stages
Single Vehicle	28.1	43.3
Head On	0.0	0.0
Angle	0.0	0.0
Rear End	13.2	17.3
Sideswipe Same	1.7	34.7
Sideswipe Opposite	0.0	0.0
Other	0.0	8.7
Total	**43.0**	**104.0**

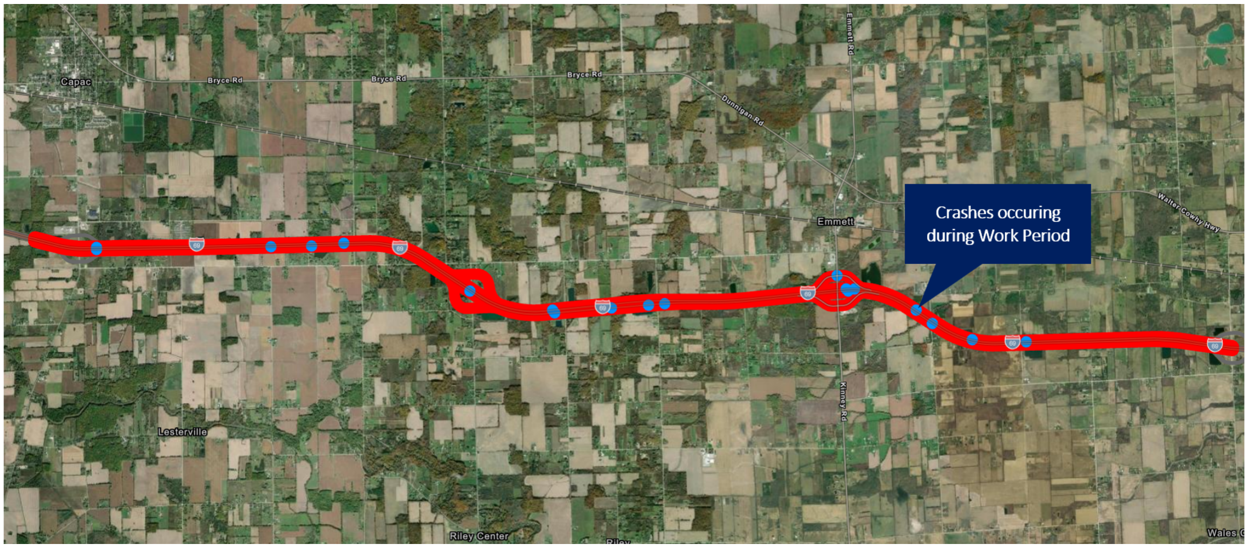
Overall, approximately 7.7 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations. This represents an increase of approximately 179.3 percent.

Total Traffic Crashes by Stage: I-75 (Old M-108 to Mackinac Bridge)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Tree Clearing and Pre-Work	Tree Clearing	3/7/2022	4/10/2022	35	0.6	0.7	0.6	2.0	+1.4	210.5%
2022 Construction Season	Single Lane Closures	4/11/2022	10/28/2022	201	3.3	4.2	3.7	10.0	+6.3	173.8%
All Stages		**3/7/2022**	**10/28/2022**	**236**	**3.9**	**5.0**	**4.3**	**12.0**	**+7.7**	**179.3%**

A.6 Reconstruction Project along I-69 (M-19 to Cox-Doty Drain)

The rural freeway project shown in the map below included approximately 6.5 miles of reconstruction work along I-69 in St. Clair County as it runs east of Capac, Michigan. The work was completed in four stages during the 2021 construction season via the use of crossovers.



Map of I-69 (M-19 to Cox-Doty Drain) Reconstruction Project

Aside from the COVID-19 pandemic, crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2021. Therefore, data from 2016-2019 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: I-69 (M-19 to Cox-Doty Drain)

Year	Average EB AADT	Average WB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	9,111	8,996	86,613,466	31	7	1	3.2%	35.8	8.1	1.2
2017	9,111	8,996	86,376,817	13	4	0	0.0%	15.1	4.6	0.0
2018	9,175	9,059	86,981,606	31	5	1	3.2%	35.6	5.7	1.1
2019	8,973	8,860	85,067,810	17	4	1	5.9%	20.0	4.7	1.2
2020	6,959	6,957	67,949,242	22	2	0	0.0%	32.4	2.9	0.0
2021	8,031	8,029	78,199,166	24	3	11	45.8%	30.7	3.8	14.1
2022	8,063	8,060	78,510,452	16	2	1	6.3%	20.4	2.5	1.3
2023	7,469	7,154	71,646,038	9	3	0	0.0%	12.6	4.2	0.0
All Years	8,362	8,264	641,344,596	163	30	15	9.2%	25.4	4.7	2.3

Traffic crash rates during the work period across the entire corridor (32.1) were similar to what is typically observed during a typical year with no construction activity (26.7 for the years 2016 to 2019). The crash rate observed during a typical construction-season along this corridor is similar (25.1) to the annual performance.

Summary of Work Zone Traffic Crash and Volume Data: I-69 (M-19 to Cox-Doty Drain)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Tree Clearing and Sign Installation	3/8/2021	4/11/2021	35	Tree Clearing	7,498,550	0	0	0		0.0	0.0	0.0
Stage 1	4/12/2021	4/27/2021	16	Single Lane Closure	3,427,909	2	0	2	100.0%	58.3	0.0	58.3
Stage 2	4/28/2021	7/13/2021	77	Crossover	16,489,890	4	0	2	50.0%	24.3	0.0	12.1
Transition to Stage 3	7/14/2021	7/22/2021	9	Crossover in Transition	1,928,199	1	0	0	0.0%	51.9	0.0	0.0
Stage 3	7/23/2021	11/12/2021	113	Crossover	24,209,605	11	1	7	63.6%	45.4	4.1	28.9
Stage 4	11/13/2021	11/24/2021	12	Single Lane Closure	2,570,931	0	0	0		0.0	0.0	0.0
All Stages	**3/8/2021**	**11/24/2021**	**262**		**56,125,083**	**18**	**1**	**11**	**61.1%**	**32.1**	**1.8**	**19.6**

Traffic Crash Rates by Worst Injury and Type: I-69 (M-19 to Cox-Doty Drain)

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.8	0.0
Severe Injury (A)	0.4	0.0
Minor Injury (B)	1.2	0.0
Possible Injury (C)	3.5	1.8
Property Damge Only	19.3	30.3
Total	**25.1**	**32.1**

Crash Type	Normal Operations	All Stages
Single Vehicle	12.4	19.6
Head On	0.0	0.0
Angle	0.4	0.0
Rear End	4.6	5.3
Sideswipe Same	5.8	1.8
Sideswipe Opposite	0.0	0.0
Other	1.9	5.3
Total	**25.1**	**32.1**

Overall, approximately 1.4 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations. This represents an increase of approximately 8.3 percent. Additionally, it is worth noting that three collisions that occurred within the transition areas greatly exceed the number of expected collisions under normal operations.

Total Traffic Crashes by Stage: I-69 (M-19 to Cox-Doty Drain)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Tree Clearing and Sign Installation	Tree Clearing	3/8/2021	4/11/2021	35	2.5	1.9	2.2	0.0	-2.2	-100.0%
Stage 1	Single Lane Closure	4/12/2021	4/27/2021	16	1.1	0.9	1.0	2.0	+1.0	97.0%
Stage 2	Crossover	4/28/2021	7/13/2021	77	5.5	4.2	4.9	4.0	-0.9	-18.1%
Transition to Stage 3	Crossover in Transition	7/14/2021	7/22/2021	9	0.6	0.5	0.6	1.0	+0.4	75.1%
Stage 3	Crossover	7/23/2021	11/12/2021	113	8.0	6.1	7.2	11.0	+3.8	53.4%
Stage 4	Single Lane Closure	11/13/2021	11/24/2021	12	0.9	0.7	0.8	0.0	-0.8	-100.0%
All Stages		**3/8/2021**	**11/24/2021**	**262**	**18.6**	**14.2**	**16.6**	**18.0**	**+1.4**	**8.3%**

Total Traffic Crashes by Area: I-69 (M-19 to Cox-Doty Drain)

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
I-69 EB	Upstream	8,053	0.7	0.2	0.5	1.0	+0.5	109.2%
	Advance Warning	8,053	1.1	0.1	0.6	1.0	+0.4	59.5%
	Transition	8,053	0.2	0.0	0.1	2.0	+1.9	1793.4%
	Activity	8,021	4.6	3.9	4.3	5.0	+0.7	16.4%
	Termination	7,939	0.1	0.0	0.1	0.0	-0.1	-100.0%
	Downstream	7,933	2.6	2.3	2.4	1.0	-1.4	-58.9%
All Northbound Areas		**8,009**	**9.3**	**6.4**	**8.0**	**10.0**	**+2.0**	**24.9%**
I-69 WB	Upstream	7,811	1.1	1.7	1.4	0.0	-1.4	-100.0%
	Advance Warning	7,844	1.1	1.0	1.0	1.0	-0.0	-4.2%
	Transition	7,886	0.1	0.2	0.2	1.0	+0.8	506.7%
	Activity	8,009	4.9	4.1	4.5	5.0	+0.5	10.3%
	Termination	8,072	0.1	0.2	0.1	0.0	-0.1	-100.0%
	Downstream	8,072	1.9	0.6	1.4	1.0	-0.4	-26.0%
All Soundbound Areas		**7,949**	**9.3**	**7.8**	**8.6**	**8.0**	**-0.6**	**-7.1%**

In general, there were not major changes in safety performance along the ramps impacted by the work activity.

Traffic Crashes by Ramp: I-69 (M-19 to Cox-Doty Drain)

Ramp Information			Average	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.	AADT	Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
EB Exit Ramp to Riley Center	0.611	EB	337	1,461	0	0	179	0	0	0.000	0.000
Riley Center EB Entrance Ramp	0.400	EB	372	1,461	1	0	179	0	0	0.001	0.000
EB Exit Ramp to M-19	0.508	EB	1,321	1,461	4	0	262	0	0	0.003	0.000
M-19 EB Entrance Ramp	0.464	EB	1,436	1,461	0	0	262	0	0	0.000	0.000
WB Exit Ramp to M-19	0.419	WB	1,092	1,461	2	0	140	0	0	0.001	0.000
M-19 WB Entrance Ramp	0.450	WB	1,144	1,461	1	0	140	1	0	0.001	0.007
WB Exit Ramp to Riley Center	0.626	WB	388	1,461	0	0	254	0	0	0.000	0.000
Riley Center WB Entrance Ramp	0.392	WB	316	1,461	0	0	132	0	0	0.000	0.000
All Ramps	**3.871**	**-**	**801**	**11,688**	**8**	**0**	**1,548**	**1**	**0**	**0.001**	**0.001**

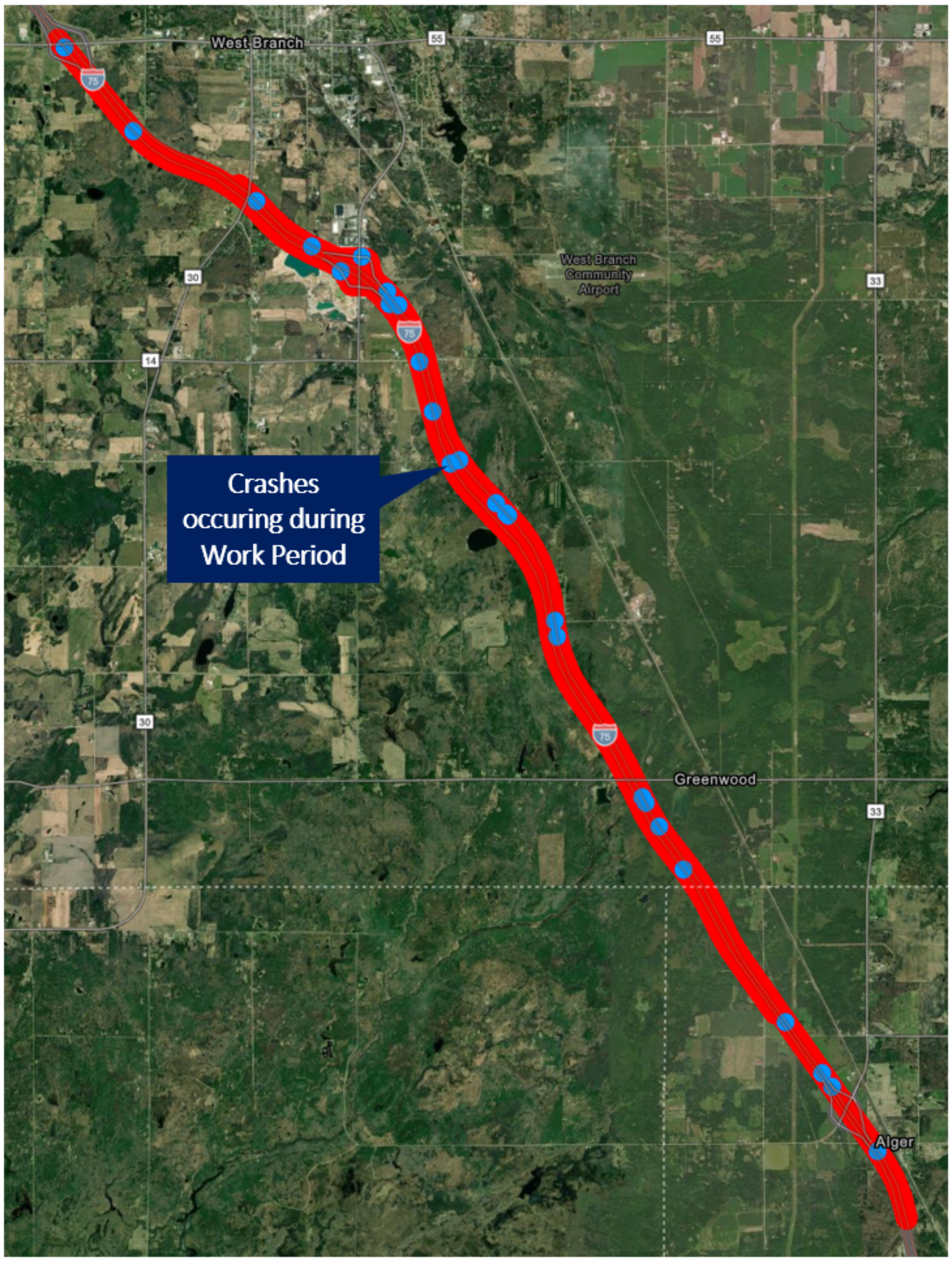
Given the review of each UD-10 crash report form diagram and narrative, the most common circumstance noted by responding officers related to work zone temporary traffic control was strikes of channelizing devices or other temporary traffic control devices (7).

Work Zone Traffic Crashes by Circumstance: I-69 (M-19 to Cox-Doty Drain)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	2	10.5%
	Vehicle(s) Struck Channelizing Devices	5	26.3%
	Sideswipe Same Collisions Related to Lane Closure	0	0.0%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	2	10.5%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	0	0.0%
	Vehicle(s) Entered Work Area	1	5.3%
	Collisions involving Work Vehicles	0	0.0%
	Collisions involving Workers	0	0.0%
	Other Work Zone Related Motor Vehicle Crashes	0	0.0%
	All Motor Vehicle Crashes Directly Related to Work Zone	**10**	**52.6%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	2	10.5%
	Other Sideswipe Same Collisions	1	5.3%
	Other Rear End Collisions	1	5.3%
	Rear End Collisions at Ramp Termini	0	0.0%
	Vehicles Striking Loose Objects on Roadway	1	5.3%
	Vehicles Struck Pedestrian on Freeway	0	0.0%
	Vehicles Struck Pedestrian at Ramp Termini	0	0.0%
	Vehicles Struck Bicyclist at Ramp Termini	0	0.0%
	Other Motor Vehicle Crashes	4	21.1%
	All Other Motor Vehicle Crashes	**9**	**47.4%**
	Total	**19**	**100.0%**

A.7 Pavement Rehabilitation Project along I-75 (Ogemaw County Line to Cook Road)

The rural freeway project shown in the map below included approximately 6.8 miles of pavement rehabilitation along I-75 in Ogemaw County. This design-build project was completed in 2017 via a series of lane closures with a lane shift. Additionally, there were limitations in identifying the timing of specific stages and associated temporary traffic control configurations. This primarily impacted the ability to determine (1) when either the left or right lane closure was in place and (2) the location of advance warning, transition and termination areas.



Map of I-75 (Ogemaw County Line to Cook Road) Pavement Rehabilitation Project

Given that this rehabilitation project occurred in the second year of the study period and the speed limit was changed in 2017, data from the post-construction period (including 2018-2019 and 2021-2023) were considered to be normal operations from a work zone perspective.

Summary of Traffic Crash/Volume Data: I-75 (Ogemaw County Line to Cook Road)

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	7,325	7,203	63,054,828	38	8	0	0.0%	60.3	12.7	0.0
2017	7,325	7,203	62,882,547	44	8	16	36.4%	70.0	12.7	25.4
2018	7,391	7,268	63,449,565	36	11	0	0.0%	56.7	17.3	0.0
2019	7,302	7,181	62,687,780	42	9	0	0.0%	67.0	14.4	0.0
2020	5,888	6,714	54,710,534	33	7	0	0.0%	60.3	12.8	0.0
2021	6,748	7,694	62,527,423	39	8	0	0.0%	62.4	12.8	0.0
2022	6,552	7,471	60,713,347	27	4	0	0.0%	44.5	6.6	0.0
2023	7,340	8,140	67,018,068	34	10	1	2.9%	50.7	14.9	1.5
All Years	**6,984**	**7,359**	**497,044,090**	**293**	**65**	**17**	**5.8%**	**58.9**	**13.1**	**3.4**

Traffic crash rates during the work period across the entire corridor (63.3) were similar to what is typically observed during a typical year with no construction activity (56.3 for the years 2018 to 2019 and 2021 to 2023). The crash rate observed during a typical construction-season along this corridor is slightly lower (47.2).

Summary of Work Zone Crash/ Volume Data: I-75 (Ogemaw County Line to Cook Road)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
All Stages	3/20/2017	10/25/2017	220	Lane Closure and Lane Shift	37,901,809	24	5	13	54.2%	63.3	13.2	34.3
All Stages	**3/20/2017**	**10/25/2017**	**220**		**37,901,809**	**24**	**5**	**13**	**54.2%**	**63.3**	**13.2**	**34.3**

Crash Rates by Worst Injury and Type: I-75 (Ogemaw County Line to Cook Road)

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.4	0.0
Severe Injury (A)	1.3	2.6
Minor Injury (B)	4.2	0.0
Possible Injury (C)	5.1	10.6
Property Damge Only	36.2	50.1
Total	**47.2**	**63.3**

Crash Type	Normal Operations	All Stages
Single Vehicle	35.0	42.2
Head On	0.0	0.0
Angle	0.0	0.0
Rear End	4.2	15.8
Sideswipe Same	7.2	5.3
Sideswipe Opposite	0.0	0.0
Other	0.8	0.0
Total	**47.2**	**63.3**

Approximately 8.8 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations. This represents an increase of approximately 58.2 percent. This increase was primarily driven by degraded performance observed along northbound I-75. In general, there were not major changes in safety performance observed along the ramps impacted by the work activity.

Total Traffic Crashes by Stage: I-75 (Ogemaw County Line to Cook Road)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
All Stages	Lane Closure and Lane Shift	3/20/2017	10/25/2017	220	12.6	17.9	15.2	24.0	+8.8	58.2%
All Stages		**3/20/2017**	**10/25/2017**	**220**	**12.6**	**17.9**	**15.2**	**24.0**	**+8.8**	**58.2%**

Total Traffic Crashes by Area: I-75 (Ogemaw County Line to Cook Road)

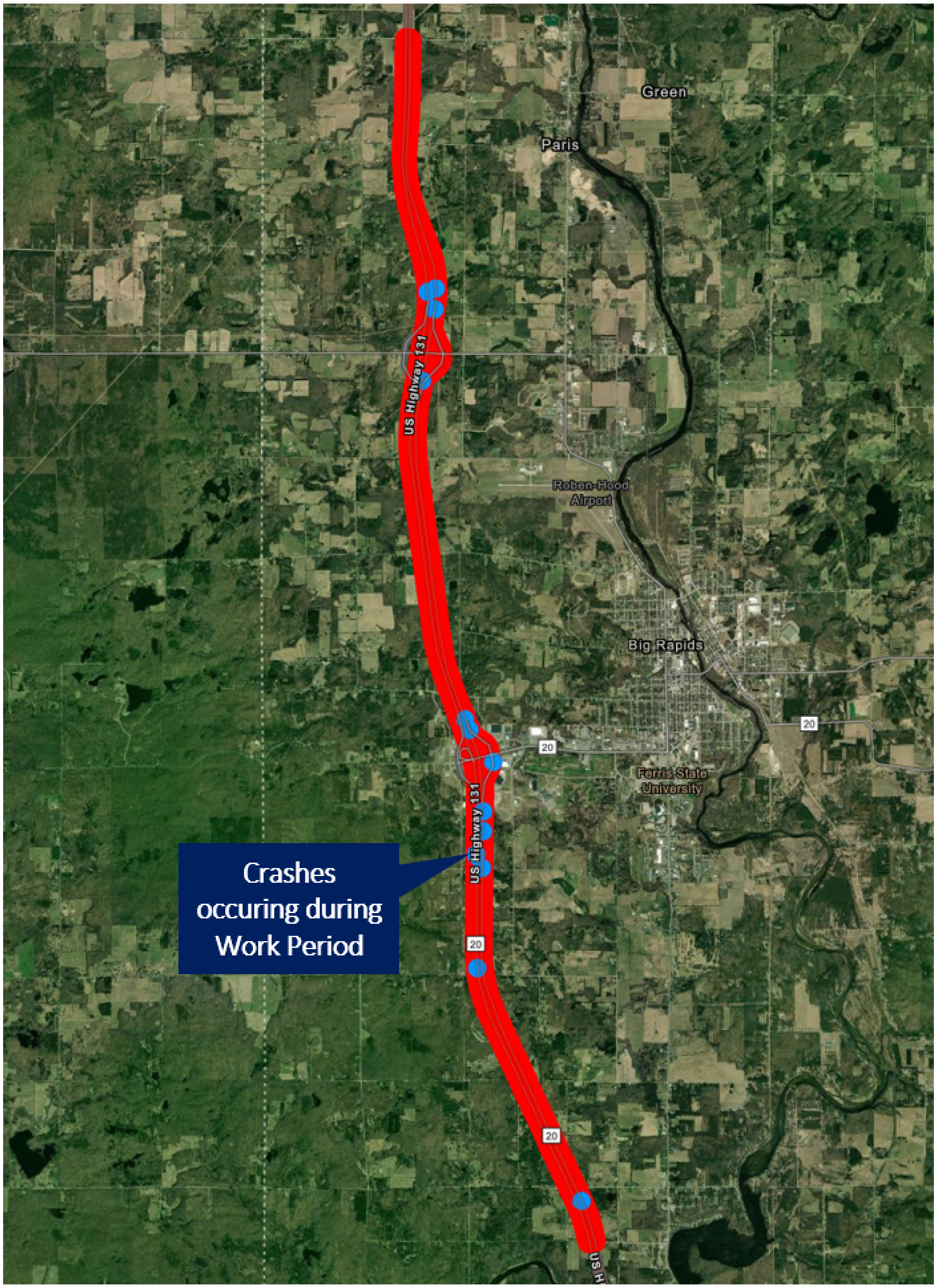
Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
I-75 NB	Upstream	7,203	1.9	3.2	2.6	4.0	+1.4	56.4%
	Activity	7,203	3.6	3.7	3.6	11.0	+7.4	202.9%
	Downstream	7,203	0.7	1.7	1.2	2.0	+0.8	67.2%
All Northbound Areas		**7,203**	**6.3**	**8.6**	**7.4**	**17.0**	**+9.6**	**130.2%**
I-75 SB	Upstream	7,325	2.0	2.5	2.2	2.0	-0.2	-10.6%
	Activity	7,325	3.6	6.0	4.8	5.0	+0.2	5.2%
	Downstream	7,325	0.8	0.8	0.8	0.0	-0.8	-100.0%
All Soundbound Areas		**7,325**	**6.3**	**9.3**	**7.8**	**7.0**	**-0.8**	**-10.0%**

Traffic Crashes by Ramp: I-75 (Ogemaw County Line to Cook Road)

Ramp Information			Average AADT	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.		Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
NB Exit Ramp to Cook Rd	0.437	NB	2,062	1,825	9	0	220	1	0	0.005	0.005
Cook Rd Entrance Ramp to NB I-75	0.329	NB	1,666	1,825	1	1	220	0	0	0.001	0.000
SB Exit Ramp to Cook Rd	0.450	SB	1,376	1,825	8	0	220	1	1	0.004	0.005
Cook Rd Entrance Ramp to SB I-75	0.308	SB	1,970	1,825	0	0	220	0	0	0.000	0.000
All Ramps	**1.525**	**-**	**1,769**	**7,300**	**18**	**1**	**880**	**2**	**1**	**0.002**	**0.002**

A.8 Resurfacing Project along Northbound US-131 (13 Mile Road to 19 Mile Road)

The project shown in the map below included approximately 6.5 miles of resurfacing work along northbound US-131 west of Big Rapids, Michigan. The project was completed via intermittent single lane closures during the 2022 construction season.



Map of Northbound US-131 (13 Mile Road to 19 Mile Road) Resurfacing Project

Aside from the COVID-19 pandemic, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2022. Therefore, data from 2017-2019 and 2021 were considered to be under normal operations from a work zone perspective (excluding data from 2016 to minimize the impact of the speed limit change).

Summary of Traffic Crash and Volume Data: US-131 (13 Mile Road to 19 Mile Road)

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	8,793	9,319	78,939,285	39	9	0	0.0%	49.4	11.4	0.0
2017	8,793	9,319	78,723,604	32	2	0	0.0%	40.6	2.5	0.0
2018	8,814	9,340	78,862,182	44	12	1	2.3%	55.8	15.2	1.3
2019	8,999	9,536	80,518,542	42	14	0	0.0%	52.2	17.4	0.0
2020	8,063	8,545	72,342,353	36	11	0	0.0%	49.8	15.2	0.0
2021	9,376	10,102	84,892,140	31	5	0	0.0%	36.5	5.9	0.0
2022	9,020	9,718	81,666,883	33	4	6	18.2%	40.4	4.9	7.3
2023	9,651	10,229	86,629,781	52	11	0	0.0%	60.0	12.7	0.0
All Years	**8,939**	**9,514**	**642,574,770**	**309**	**68**	**7**	**2.3%**	**48.1**	**10.6**	**1.1**

Traffic crash rates during the work period across the entire corridor (52.3) were similar to what is typically observed during a typical year with no construction activity (46.1 for the years 2017 to 2019 and 2021). The crash rate observed during a typical construction-season along this corridor is considerably lower (37.6), where the rate of single vehicle and sideswipe same crashes were considerably larger during the work period for the entire corridor.

Summary of Work Zone Crash and Volume Data: US-131 (13 Mile Road to 19 Mile Road)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
All Stages	7/11/2022	10/29/2022	111	Intermittent Single Lane Closures	24,834,689	13	1	6	46.2%	52.3	4.0	24.2
All Stages	**7/11/2022**	**10/29/2022**	**111**		**24,834,689**	**13**	**1**	**6**	**46.2%**	**52.3**	**4.0**	**24.2**

Crash Rates by Worst Injury and Type: US-131 (13 Mile Road to 19 Mile Road)

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.0	0.0
Severe Injury (A)	1.7	0.0
Minor Injury (B)	1.7	4.0
Possible Injury (C)	5.4	0.0
Property Damge Only	28.9	48.3
Total	**37.6**	**52.3**

Crash Type	Normal Operations	All Stages
Single Vehicle	22.7	28.2
Head On	0.0	0.0
Angle	0.0	0.0
Rear End	7.0	8.1
Sideswipe Same	5.4	16.1
Sideswipe Opposite	0.0	0.0
Other	2.5	0.0
Total	**37.6**	**52.3**

The seven crashes that occurred within the activity area along northbound US-131 represented an increase of approximately 4.8 crashes than would have been expected under normal operations. In general, there were not major changes in safety performance along the ramps impacted by the work activity.

Total Traffic Crashes by Area: US-131 (13 Mile Road to 19 Mile Road)

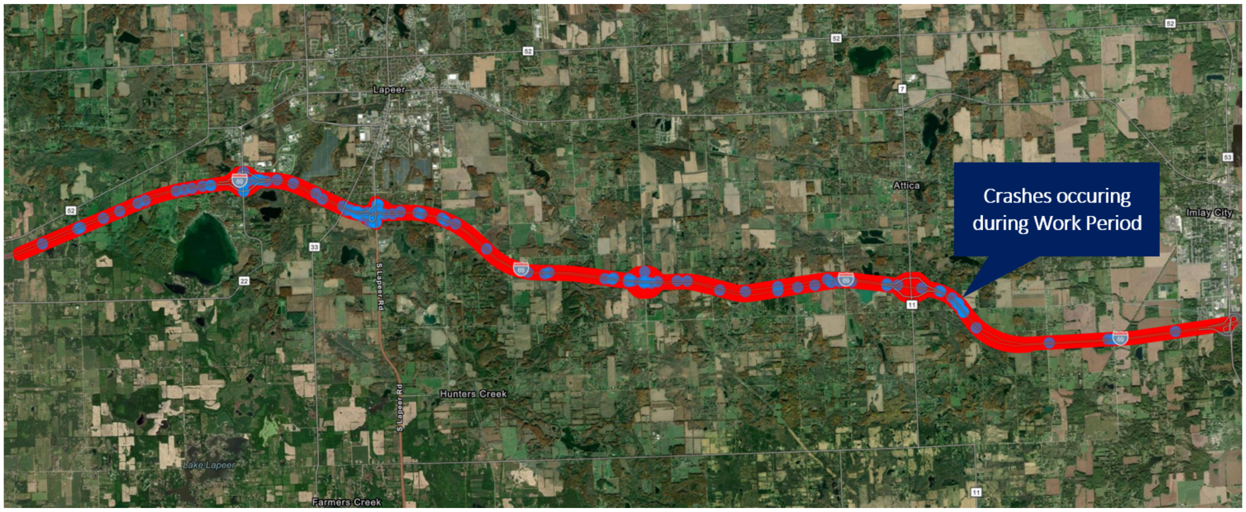
Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
US-131 NB	Upstream	10,650	1.1	1.9	1.5	1.0	-0.5	-32.2%
	Activity	9,718	2.3	2.2	2.2	7.0	+4.8	212.1%
	Downstream	9,664	0.9	0.4	0.7	1.0	+0.3	52.8%
All Northbound Areas		**10,011**	**4.2**	**4.5**	**4.4**	**9.0**	**+4.6**	**105.8%**
US-131 SB	Upstream	8,969	0.8	0.9	0.9	1.0	+0.1	14.8%
	Activity	9,020	2.1	3.0	2.5	3.0	+0.5	18.2%
	Downstream	10,155	1.0	0.8	0.9	0.0	-0.9	-100.0%
All Soundbound Areas		**9,381**	**3.9**	**4.7**	**4.3**	**4.0**	**-0.3**	**-7.2%**

Traffic Crashes by Ramp: US-131 (13 Mile Road to 19 Mile Road)

Ramp Information			Average AADT	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.		Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
NB Exit Ramp to Perry Ave	0.461	NB	3,835	1,460	38	0	111	1	1	0.026	0.009
Perry Ave NB Entrance Ramp	0.429	NB	2,876	1,460	4	0	111	0	0	0.003	0.000
NB Exit Ramp to 19 Mile Rd	0.552	NB	1,736	1,460	4	0	111	0	0	0.003	0.000
19 Mile Road NB Entrance Ramp	0.405	NB	667	1,460	0	0	111	0	0	0.000	0.000
All Ramps	**1.847**	**-**	**2,279**	**5,840**	**46**	**0**	**444**	**1**	**1**	**0.008**	**0.002**

A.9 Reconstruction Project along I-69 (M-24 to Lake George Road)

The suburban freeway project shown in the map below included approximately 7.0 miles of pavement reconstruction along I-69 between Lapeer and Imlay City, Michigan. The work was completed via a series of crossovers during the 2022 and 2023 construction seasons.



Map of I-69 (M-24 to Lake George Road) Reconstruction Project

Aside from the COVID-19 pandemic and a prior construction project in 2016, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2022. Therefore, data from 2017-2019 and 2021 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: I-69 (M-24 to Lake George Road)

Year	Average EB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	14,217	13,758	158,862,493	60	10	12	20.0%	37.8	6.3	7.6
2017	14,213	13,758	158,402,746	39	11	0	0.0%	24.6	6.9	0.0
2018	14,231	13,778	158,648,294	75	17	2	2.7%	47.3	10.7	1.3
2019	14,176	14,121	160,249,283	84	17	4	4.8%	52.4	10.6	2.5
2020	11,684	11,635	132,427,075	35	16	1	2.9%	26.4	12.1	0.8
2021	13,483	13,427	152,402,695	44	12	3	6.8%	28.9	7.9	2.0
2022	12,802	12,275	141,641,333	51	11	18	35.3%	36.0	7.8	12.7
2023	13,173	12,325	143,958,569	62	11	13	21.0%	43.1	7.6	9.0
All Years	13,497	13,135	1,206,592,488	450	105	53	11.8%	37.3	8.7	4.4

Traffic crash rates during the work period across the entire corridor (39.8) were similar to what is typically observed during a typical year with no construction activity (38.4 for the years 2017 to 2019 and 2021). The crash rate observed during a typical construction-season along this corridor is slightly lower (32.2). It should be noted that crash rates were highest during the winter shutdown period (77.0), where the crash rate during the work activity was considerably lower (32.3).

Summary of Work Zone Traffic Crash and Volume Data: I-69 (M-24 to Lake George Road)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Pre-Stage and Tree Clearing	3/21/2022	4/17/2022	28	Pre-Stage Work	10,530,841	2	0	1	50.0%	19.0	0.0	9.5
Stage 1	4/18/2022	5/19/2022	32	Crossover Construction	12,073,649	7	1	2	28.6%	58.0	8.3	16.6
Stage 2	5/20/2022	12/7/2022	202	Crossover (in EB Roadbed)	77,587,719	23	8	15	65.2%	29.6	10.3	19.3
Winter 2023	12/8/2022	3/19/2023	102	All Lanes Open	38,974,556	30	6	0	0.0%	77.0	15.4	0.0
Pre-Stage 3 Work	3/20/2023	3/31/2023	12	Pre-Stage Work	4,584,537	2	0	1	50.0%	43.6	0.0	21.8
Stage 3	4/1/2023	9/23/2023	176	Crossover (in WB Roadbed)	68,578,047	25	2	12	48.0%	36.5	2.9	17.5
Stage 4	9/24/2023	11/18/2023	56	Project Closeout	21,394,504	4	2	0	0.0%	18.7	9.3	0.0
All Stages	**3/21/2022**	**11/18/2023**	**608**		**233,723,854**	**93**	**19**	**31**	**33.3%**	**39.8**	**8.1**	**13.3**

Crash Rates by Worst Injury/Type: I-69 (M-24 to Lake George Rd.) – *Excludes Winter Shutdown*

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.0	0.0
Severe Injury (A)	0.2	1.0
Minor Injury (B)	2.8	3.1
Possible Injury (C)	3.8	2.6
Property Damge Only	25.4	25.7
Total	**32.2**	**32.3**

Crash Type	Normal Operations	All Stages
Single Vehicle	18.6	14.9
Head On	0.0	0.5
Angle	0.6	0.5
Rear End	3.4	7.7
Sideswipe Same	7.2	7.2
Sideswipe Opposite	0.0	0.0
Other	2.3	1.5
Total	**32.2**	**32.3**

It is important to recognize that this corridor has historically exhibited exceptional safety performance under normal operations, largely due to the fact the corridor serves approximately 25,000 vehicles per day without considerable recurring congestion that leads to rear end collisions. This exceptional safety performance was largely maintained during the work period.

Total Traffic Crashes by Stage: I-69 (M-24 to Lake George Road)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Pre-Stage and Tree Clearing	Pre-Stage Work	3/21/2022	4/17/2022	28	5.9	3.4	4.2	2.0	-2.2	-52.6%
Stage 1	Crossover Construction	4/18/2022	5/19/2022	32	6.8	3.9	4.8	7.0	+2.2	44.7%
Stage 2	Crossover (in EB Roadbed)	5/20/2022	12/7/2022	202	43.5	24.5	30.6	23.0	-7.6	-24.9%
Winter 2023	All Lanes Open	12/8/2022	3/19/2023	102	45.4	22.6	31.6	30.0	-1.6	-5.2%
Pre-Stage 3 Work	Pre-Stage Work	3/20/2023	3/31/2023	12	2.6	1.5	1.8	2.0	+0.2	9.6%
Stage 3	Crossover (in WB Roadbed)	4/1/2023	9/23/2023	176	38.5	21.6	26.9	25.0	-1.9	-7.1%
Stage 4	Project Closeout	9/24/2023	11/18/2023	56	12.0	6.8	8.5	4.0	-4.5	-53.0%
All Stages		**3/21/2022**	**11/18/2023**	**608**	**154.7**	**84.2**	**108.6**	**93.0**	**-15.6**	**-14.3%**

Total Crashes by Area: I-69 (M-24 to Lake George Rd.) – *Excludes Winter Shutdown*

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	**Area**	**Average AADT**	**Predicted from Similar Sites**	**Observed**	**Expected**	**Observed**	**Estimated Change**	**Percent Change**
I-69 EB	Upstream	15,727	4.4	2.4	2.9	3.0	+0.1	2.3%
	Advance Warning	14,669	10.8	6.6	7.8	8.0	+0.2	3.0%
	Transition	14,669	1.6	1.0	1.2	1.0	-0.2	-14.6%
	Activity	12,293	36.1	15.5	22.2	16.0	-6.2	-27.9%
	Termination	10,880	1.0	1.1	1.0	2.0	+1.0	92.5%
	Downstream	10,933	3.1	0.8	1.6	1.0	-0.6	-36.8%
All Eastbound Areas		**13,195**	**56.9**	**27.3**	**36.7**	**31.0**	**-5.7**	**-15.5%**
I-69 WB	Upstream	10,961	3.1	2.3	2.6	0.0	-2.6	-100.0%
	Advance Warning	10,961	8.8	4.6	6.1	4.0	-2.1	-33.9%
	Transition	10,882	1.3	1.3	1.3	2.0	+0.7	52.0%
	Activity	12,433	32.3	21.5	25.1	18.0	-7.1	-28.3%
	Termination	15,143	2.5	1.4	1.7	0.0	-1.7	-100.0%
	Downstream	15,216	4.3	3.2	3.5	8.0	+4.5	129.7%
All Westbound Areas		**12,599**	**52.4**	**34.3**	**40.2**	**32.0**	**-8.2**	**-20.5%**

In general, there were not major changes in safety performance along the ramps impacted by the work activity. Given the review of each UD-10 crash report form diagram and narrative, the most common circumstance directly related to work zone temporary traffic control were rear end collisions related to vehicles stopping or slowing.

Traffic Crashes by Ramp: I-69 (M-24 to Lake George Road)

Ramp Information			Average AADT	Normal Operations			All Stages			Crashes per Day	
Description	**Length**	**Dir.**		**Days**	**Total**	**WZ Coded**	**Days**	**Total**	**WZ Coded**	**Normal**	**All Stages**
EB Exit Ramp to Lake Nepessing Rd	0.392	EB	3,082	1,460	4	0	608	3	0	0.003	0.005
Lake Nepessing Rd EB Entrance Ramp	0.367	EB	1,503	1,460	5	0	608	0	0	0.003	0.000
EB Exit Ramp to M-24	0.344	EB	6,568	1,460	24	0	608	9	1	0.016	0.015
SB M-24 EB Entrance Ramp	0.246	EB	1,771	1,460	2	0	432	0	0	0.001	0.000
NB M-24 EB Entrance Ramp	0.360	EB	969	1,460	2	0	432	1	0	0.001	0.002
EB Exit Ramp to Wilder Rd	0.472	EB	919	1,460	5	0	432	0	0	0.003	0.000
Wilder Rd EB Entrance Ramp	0.381	EB	906	1,460	0	0	432	0	0	0.000	0.000
EB Exit Ramp to Lake Pleasant Rd	0.476	EB	1,708	1,460	1	0	608	1	0	0.001	0.002
Lake Pleasant Rd EB Entrance Ramp	0.409	EB	634	1,460	2	0	608	0	0	0.001	0.000
WB Exit Ramp to Lake Pleasant Rd	0.440	WB	1,719	1,460	2	0	608	0	0	0.001	0.000
Lake Pleasant Rd WB Entrance Ramp	0.370	WB	1,719	1,460	3	0	608	1	1	0.002	0.002
WB Exit Ramp to Wilder Rd	0.478	WB	888	1,460	0	0	406	1	1	0.000	0.002
Wilder Rd WB Entrance Ramp	0.391	WB	913	1,460	1	0	406	1	1	0.001	0.002
WB Exit Ramp to M-24	0.417	WB	2,802	1,460	33	0	406	6	0	0.023	0.015
NB M-24 WB Entrance Ramp	0.256	WB	1,985	1,460	0	0	406	0	0	0.000	0.000
SB M-24 WB Entrance Ramp	0.343	WB	1,985	1,460	5	0	406	0	0	0.003	0.000
WB Exit Ramp to Lake Nepessing Rd	0.377	WB	1,541	1,460	4	0	608	1	0	0.003	0.002
Lake Nepessing Rd WB Entrance Ramp	0.375	WB	2,848	1,460	2	0	608	0	0	0.001	0.000
All Ramps	**6.895**	**-**	**1,914**	**26,280**	**95**	**0**	**9,230**	**24**	**4**	**0.004**	**0.003**

Work Zone Traffic Crashes by Circumstance: I-69 (M-24 to Lake George Road)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	1	0.9%
	Vehicle(s) Struck Channelizing Devices	4	3.4%
	Sideswipe Same Collisions Related to Lane Closure	1	0.9%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	10	8.5%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	0	0.0%
	Vehicle(s) Entered Work Area	2	1.7%
	Collisions involving Work Vehicles	0	0.0%
	Collisions involving Workers	0	0.0%
	Other Work Zone Related Motor Vehicle Crashes	5	4.3%
	All Motor Vehicle Crashes Directly Related to Work Zone	**23**	**19.7%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	44	37.6%
	Other Sideswipe Same Collisions	15	12.8%
	Other Rear End Collisions	7	6.0%
	Rear End Collisions at Ramp Termini	16	13.7%
	Vehicles Striking Loose Objects on Roadway	4	3.4%
	Vehicles Struck Pedestrian on Freeway	0	0.0%
	Vehicles Struck Pedestrian at Ramp Termini	0	0.0%
	Vehicles Struck Bicyclist at Ramp Termini	0	0.0%
	Other Motor Vehicle Crashes	8	6.8%
	All Other Motor Vehicle Crashes	**94**	**80.3%**
	Total	**117**	**100.0%**

A.10 Reconstruction Project along US-31 (I-196 NB to Central Avenue)

The suburban freeway project shown in the map below included approximately 2.8 miles of reconstruction work along US-31 south of Holland in Allegan County. The work was completed in three stages during the 2022 construction season, where a full closure and detour of northbound US-31 was employed for the majority of the project. Southbound traffic was crossed over to the northbound roadbed to complete that portion of the southbound roadbed.

Map of US-31 (I-196 NB to Central Avenue) Reconstruction Project

Aside from the COVID-19 pandemic and a prior construction project in 2021, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2022. Therefore, data from 2016 to 2019 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: US-31 (I-196 NB to Central Avenue)

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	14,172	14,345	47,121,336	26	5	0	0.0%	55.2	10.6	0.0
2017	14,172	14,345	46,992,590	24	3	0	0.0%	51.1	6.4	0.0
2018	14,249	14,428	47,284,894	28	12	0	0.0%	59.2	25.4	0.0
2019	14,222	14,413	47,058,945	24	6	0	0.0%	51.0	12.7	0.0
2020	12,641	13,052	41,912,714	18	4	0	0.0%	42.9	9.5	0.0
2021	14,361	14,796	47,496,718	30	5	13	43.3%	63.2	10.5	27.4
2022	14,182	14,578	46,915,835	34	6	4	11.8%	72.5	12.8	8.5
2023	14,640	15,056	48,428,008	20	6	1	5.0%	41.3	12.4	2.1
All Years	**14,080**	**14,377**	**373,211,039**	**204**	**47**	**18**	**8.8%**	**54.7**	**12.6**	**4.8**

Traffic crash rates during the work period across the entire corridor (42.7) were less than what is typically observed during a typical year with no construction activity (54.1 for the years 2016 to 2019). However, the crash rate observed during a typical construction-season along this corridor is slightly lower (44.6), where performance during the work zone period was similar.

Summary of WZ Traffic Crash and Volume Data: US-31 (I-196 NB to Central Avenue)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Stages 1a/1b	3/14/2022	7/13/2022	122	NB Closed, SB in SB Roadbed	12,930,125	4	1	1	25.0%	30.9	7.7	7.7
Stages 2a/2b	7/14/2022	10/2/2022	81	NB Closed, SB in NB Roadbed	8,584,755	5	1	3	60.0%	58.2	11.6	34.9
Stage 3	10/3/2022	10/17/2022	15	Shoulder and Single Lane Closures	1,928,048	1	0	0	0.0%	51.9	0.0	0.0
All Stages	**3/14/2022**	**10/17/2022**	**218**		**23,442,929**	**10**	**2**	**4**	**40.0%**	**42.7**	**8.5**	**17.1**

Crash Rates by Worst Injury and Type: US-31 (I-196 NB to Central Avenue)

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.0	0.0
Severe Injury (A)	0.7	0.0
Minor Injury (B)	8.5	8.5
Possible Injury (C)	5.0	0.0
Property Damge Only	30.4	34.1
Total	**44.6**	**42.7**

Crash Type	Normal Operations	All Stages
Single Vehicle	28.3	21.3
Head On	0.0	0.0
Angle	0.0	0.0
Rear End	6.4	4.3
Sideswipe Same	7.8	17.1
Sideswipe Opposite	0.0	0.0
Other	2.1	0.0
Total	**44.6**	**42.7**

Overall, there was not a considerable impact on expected safety performance along the corridor during the work period.

Total Traffic Crashes by Stage: US-31 (I-196 NB to Central Avenue)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Stages 1a/1b	NB Closed, SB in SB Roadbed	3/14/2022	7/13/2022	122	7.2	6.5	6.8	4.0	-2.8	-41.5%
Stages 2a/2b	NB Closed, SB in NB Roadbed	7/14/2022	10/2/2022	81	4.8	4.3	4.5	5.0	+0.5	10.1%
Stage 3	Shoulder and Single Lane Closures	10/3/2022	10/17/2022	15	1.1	0.9	1.0	1.0	+0.0	2.7%
All Stages		**3/14/2022**	**10/17/2022**	**218**	**13.0**	**11.6**	**12.4**	**10.0**	**-2.4**	**-19.0%**

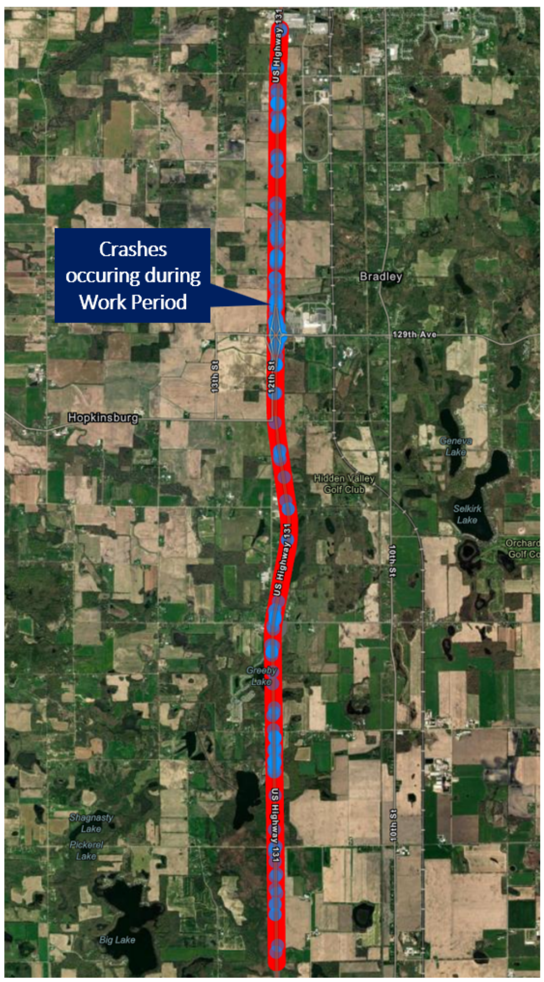
In general, there were not major changes in safety performance along the ramps impacted by the work activity. However, it should be noted that the adjacent system interchange with I-196 was impacted by the work, where temporary traffic control along westbound resulted in a pattern of collisions as vehicles attempted to merge onto southbound US-31.

Traffic Crashes by Ramp: US-31 (I-196 NB to Central Avenue)

Ramp Information			Average	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.	AADT	Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
I-196 EB	1.708	EB	8,344	1,461	9	0	218	0	0	0.006	0.000
I-196 WB	1.729	WB	8,754	1,461	14	0	218	4	1	0.010	0.018
NB Exit Ramp to SB Washington Ave	0.222	NB	226	1,461	2	0	0	0	0	0.001	0.000
NB Exit Ramp to NB Washington Ave	0.159	NB	1,883	1,461	1	0	0	0	0	0.001	0.000
Washington Ave NB Entrance Ramp	0.259	NB	3,790	1,461	6	0	0	0	0	0.004	0.000
SB Exit Ramp to NB Washington Ave	0.157	WB	2,825	1,461	13	0	218	1	0	0.009	0.005
Washington Ave SB Entrance Ramp	0.309	SB	2,108	1,461	3	0	218	0	0	0.002	0.000
SB Exit Ramp to SB Washington Ave	0.235	SB	2,423	1,461	3	0	218	0	0	0.002	0.000
All Ramps	**4.778**	**-**	**3,794**	**11,688**	**51**	**0**	**1,090**	**5**	**1**	**0.004**	**0.005**

A.11 SPUI Conversion and Resurfacing Project along US-131 (at M-179 Interchange)

The rural freeway project shown in the map below included approximately 7.2 miles of resurfacing and reconstruction work along US-31 between Grand Rapids and Kalamazoo. The work was completed during the 2021, 2022, and 2023 construction seasons. The project also included the conversion of the service interchange at M-179 (129th Avenue) to a single point urban interchange. While the larger resurfacing and reconstruction work was completed via intermittent lane and shoulder closures, the shorter interchange conversion effort was completed with crossovers adjacent to the interchange. Additionally, there were limitations in identifying the timing of specific stages and associated temporary traffic control configurations. As a result, the project is evaluated as a single stage where details of the temporary traffic control configuration are limited beyond identifying the location of the larger pavement work versus the interchange conversion effort.



Map of US-131 (at M-179 Interchange) SPUI Conversion and Resurfacing Project

Aside from the COVID-19 pandemic, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2021. Therefore, data from 2016 to 2019 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: US-131 (at M-179 Interchange)

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	20,028	19,923	118,099,361	78	11	0	0.0%	66.0	9.3	0.0
2017	20,028	19,923	117,776,685	90	12	0	0.0%	76.4	10.2	0.0
2018	20,116	20,011	118,323,525	79	12	1	1.3%	66.8	10.1	0.8
2019	20,275	20,044	118,614,956	117	15	2	1.7%	98.6	12.6	1.7
2020	16,703	15,886	95,981,769	47	7	1	2.1%	49.0	7.3	1.0
2021	18,975	18,471	110,024,462	107	15	31	29.0%	97.3	13.6	28.2
2022	19,051	18,545	110,465,150	88	13	11	12.5%	79.7	11.8	10.0
2023	19,555	19,868	116,107,466	69	8	0	0.0%	59.4	6.9	0.0
All Years	**19,341**	**19,084**	**905,393,374**	**675**	**93**	**46**	**6.8%**	**74.6**	**10.3**	**5.1**

Traffic crash rates during the work period across the entire corridor (79.0) were similar to what is typically observed during a typical year with no construction activity (77.0 for the years 2016 to 2019). However, the crash rate observed during a typical construction-season along this corridor is considerably lower (59.5), where the corridor experienced larger rates of single vehicle, rear end, and sideswipe same collisions.

Summary of Work Zone Traffic Crash and Volume Data: US-131 (at M-179 Interchange)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
All Stages	3/1/2021	10/31/2022	610	Single Lane Closures with SPUI Conversion	189,770,236	150	23	42	28.0%	79.0	12.1	22.1
All Stages	**3/1/2021**	**10/31/2022**	**610**		**189,770,236**	**150**	**23**	**42**	**28.0%**	**79.0**	**12.1**	**22.1**

Traffic Crash Rates by Worst Injury and Type: US-131 (at M-179 Interchange)

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.6	0.5
Severe Injury (A)	1.4	1.6
Minor Injury (B)	2.5	6.3
Possible Injury (C)	5.4	3.7
Property Damge Only	49.6	66.9
Total	**59.5**	**79.0**

Crash Type	Normal Operations	All Stages
Single Vehicle	36.1	42.2
Head On	0.6	0.0
Angle	0.3	0.0
Rear End	10.7	16.9
Sideswipe Same	7.9	16.9
Sideswipe Opposite	0.0	0.0
Other	3.9	3.2
Total	**59.5**	**79.0**

Overall, approximately 39.6 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations. This represents an increase of approximately 35.8 percent. Intuitively, the smaller area where the interchange work was performed experienced considerably larger estimated impacts compared to the larger paving effort. In general, there were not major changes in safety performance along the ramps impacted by the work activity.

Total Traffic Crashes by Stage: US-131 (at M-179 Interchange)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
All Stages	Single Lane Closures with SPUI Conversion	3/1/2021	10/31/2022	610	104.0	112.5	110.4	150.0	+39.6	35.8%
All Stages		**3/1/2021**	**10/31/2022**	**610**	**104.0**	**112.5**	**110.4**	**150.0**	**+39.6**	**35.8%**

Total Traffic Crashes by Activity Type: US-131 (at M-179 Interchange)

Type of Activity	VMT	Crashes during Normal Operations			Crashes during Work Zone Operations		
		Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Intermittent Lane and Shoulder Closures	140,036,995	76.7	74.9	75.3	93.0	**+17.7**	**23.5%**
Interchange Work	12,140,865	6.7	14.9	13.0	37.0	**+24.0**	**185.5%**

Traffic Crashes by Ramp: US-131 (at M-179 Interchange)

Ramp Information			Average AADT	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.		Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
NB Exit to M-179	0.155	NB	1,474	1,461	20	0	610	6	4	0.014	0.010
M-179 NB Entrance Ramp	0.145	NB	4,508	1,461	4	0	610	3	2	0.003	0.005
SB Exit to M-179	0.111	SB	3,891	1,461	6	0	610	2	1	0.004	0.003
M-179 SB Entrance Ramp	0.077	SB	1,549	1,461	2	0	610	1	0	0.001	0.002
All Ramps	**0.488**	**-**	**2,855**	**5,844**	**32**	**0**	**2,440**	**12**	**7**	**0.005**	**0.005**

A.12 Resurfacing Project along I-94 (Red Arrow Highway to Stevensville)

The suburban freeway project shown in the map below included approximately 5.8 miles of resurfacing along eastbound I-94 in Berrien County. The work was completed during the 2017 construction season primarily via single lane closures with double lane closures employed at night.

Map of I-94 (Red Arrow Highway to Stevensville) Resurfacing Project

Aside from the COVID-19 pandemic and a prior construction project in 2016, traffic crash and volume data were relatively consistent after the implementation of work zone temporary traffic control in 2017. Therefore, data from 2018-2019 and 2021-2023 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: I-94 (Red Arrow Highway to Stevensville)

Year	Average EB AADT	Average WB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	22,706	20,848	208,379,456	199	28	70	35.2%	95.5	13.4	33.6
2017	22,706	20,848	207,810,113	169	27	34	20.1%	81.3	13.0	16.4
2018	23,020	20,996	210,011,286	127	13	8	6.3%	60.5	6.2	3.8
2019	23,484	21,429	214,293,624	199	28	3	1.5%	92.9	13.1	1.4
2020	22,286	21,252	208,307,957	128	24	0	0.0%	61.4	11.5	0.0
2021	22,139	21,025	205,997,039	111	17	0	0.0%	53.9	8.3	0.0
2022	22,483	21,416	209,481,403	149	18	3	2.0%	71.1	8.6	1.4
2023	24,548	22,990	227,166,691	147	24	0	0.0%	64.7	10.6	0.0
All Years	**22,921**	**21,350**	**1,691,447,570**	**1,229**	**179**	**118**	**9.6%**	**72.7**	**10.6**	**7.0**

Crash rates during the work period across the entire corridor (58.0) were less than what is typically observed during a typical year with no construction activity (68.7 for the years 2018 to 2019 and 2021 to 2023). However, the crash rate observed during a typical construction-season along this corridor is slightly lower (55.2), where performance across the corridor during the work zone period was similar.

Summary of WZ Traffic Crash and Volume Data: I-94 (Red Arrow Highway to Stevensville)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Pre-Stage	3/1/2017	4/16/2017	47	Pre-Stage Work	26,759,110	7	0	0	0.0%	26.2	0.0	0.0
All Stages	4/17/2017	9/22/2017	159	Daily Single Lane w/ Nightly Double Lane Closures	90,525,501	61	14	34	55.7%	67.4	15.5	37.6
All Stages	**3/1/2017**	**9/22/2017**	**206**		**117,284,612**	**68**	**14**	**34**	**50.0%**	**58.0**	**11.9**	**29.0**

Traffic Crash Rates by Worst Injury and Type: I-94 (Red Arrow Highway to Stevensville)

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.6	0.9
Severe Injury (A)	0.7	3.4
Minor Injury (B)	2.7	4.3
Possible Injury (C)	4.9	3.4
Property Damge Only	46.2	46.0
Total	**55.2**	**58.0**

Crash Type	Normal Operations	All Stages
Single Vehicle	36.9	29.0
Head On	0.0	0.0
Angle	0.2	0.0
Rear End	3.2	14.5
Sideswipe Same	11.2	11.1
Sideswipe Opposite	0.0	0.0
Other	3.6	3.4
Total	**55.2**	**58.0**

It can be observed from isolating the eastbound I-94, approximately 11.5 additional traffic crashes are estimated to have occurred during the study work period than would have been expected under normal operations. In general, there were not major changes in safety performance along the ramps impacted by the work activity. Given the review of each UD-10 crash report form diagram and narrative, the most common circumstance directly related to work zone temporary traffic control were rear end collisions related to vehicles stopping or slowing.

Total Traffic Crashes by Area: I-94 (Red Arrow Highway to Stevensville)

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
All Westbound Areas		20,848	30.7	32.5	32.2	24.0	-8.2	-25.5%
I-94 EB	Upstream	22,524	2.5	2.4	2.4	1.0	-1.4	-58.2%
	Advance Warning	22,618	6.3	5.6	5.7	4.0	-1.7	-30.3%
	Transition	22,711	1.0	0.6	0.6	3.0	+2.4	367.5%
	Activity	22,759	19.8	18.2	18.5	32.0	+13.5	73.2%
	Termination	22,768	1.2	2.0	1.9	4.0	+2.1	110.2%
	Downstream	22,768	2.3	3.5	3.3	0.0	-3.3	-100.0%
All Eastbound Areas		22,691	33.2	32.3	32.5	44.0	+11.5	35.5%

Traffic Crashes by Ramp: I-94 (Red Arrow Highway to Stevensville)

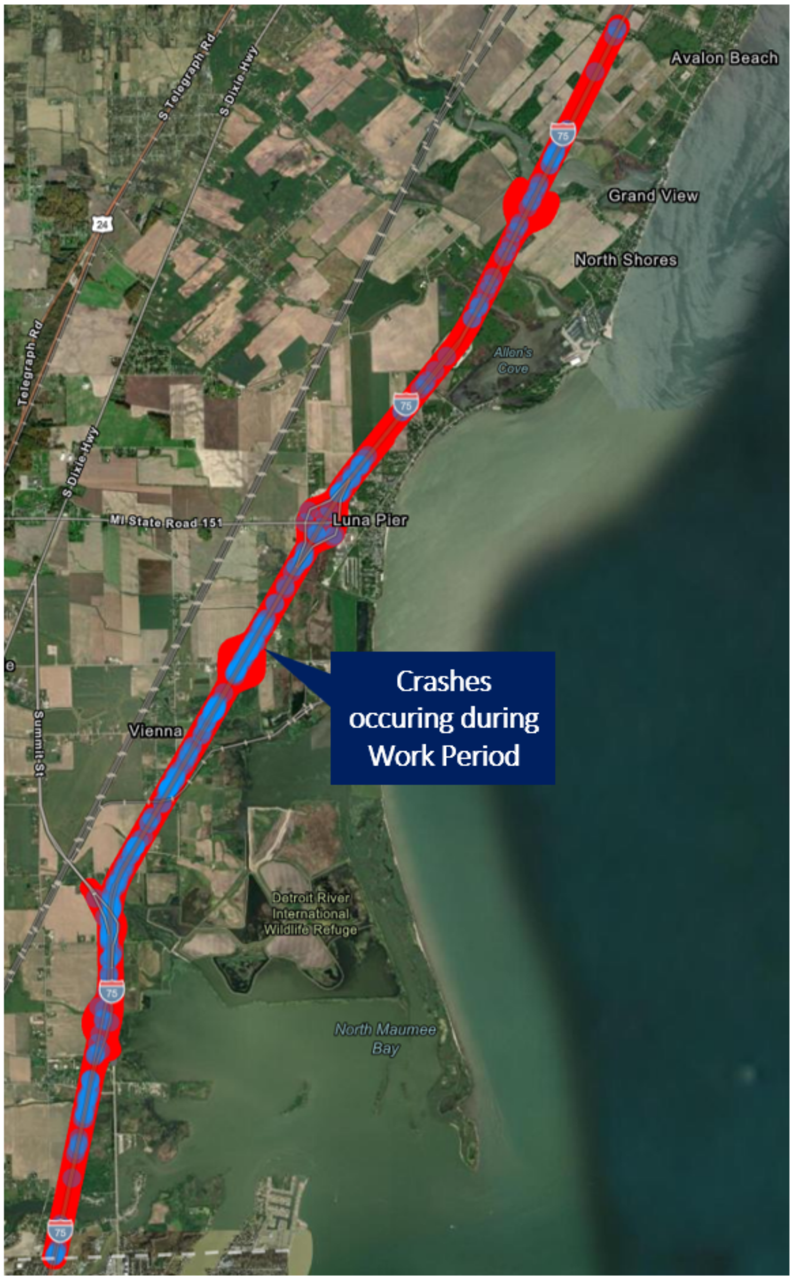
Ramp Information			Average	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.	AADT	Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
EB Red Arrow Hwy Exit Ramp	0.325	EB	1,041	1,825	5	0	206	0	0	0.003	0.000
Red Arrow Hwy EB Entrance Ramp	0.302	EB	821	3,650	2	0	412	0	0	0.001	0.000
EB John Beers Rd Exit Ramp	0.271	EB	658	1,825	0	0	196	1	0	0.000	0.005
John Beers Rd EB Entrance Ramp	0.224	EB	641	1,825	3	0	196	0	0	0.002	0.000
All Ramps	1.121	-	790	9,125	10	0	1,010	1	0	0.001	0.001

Work Zone Traffic Crashes by Circumstance: I-94 (Red Arrow Highway to Stevensville)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	2	2.9%
	Vehicle(s) Struck Channelizing Devices	4	5.8%
	Sideswipe Same Collisions Related to Lane Closure	1	1.4%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	14	20.3%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	2	2.9%
	Vehicle(s) Entered Work Area	0	0.0%
	Collisions involving Work Vehicles	0	0.0%
	Collisions involving Workers	0	0.0%
	Other Work Zone Related Motor Vehicle Crashes	2	2.9%
	All Motor Vehicle Crashes Directly Related to Work Zone	**25**	**36.2%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	23	33.3%
	Other Sideswipe Same Collisions	8	11.6%
	Other Rear End Collisions	2	2.9%
	Rear End Collisions at Ramp Termini	0	0.0%
	Vehicles Striking Loose Objects on Roadway	3	4.3%
	Vehicles Struck Pedestrian on Freeway	1	1.4%
	Vehicles Struck Pedestrian at Ramp Termini	0	0.0%
	Vehicles Struck Bicyclist at Ramp Termini	0	0.0%
	Other Motor Vehicle Crashes	7	10.1%
	All Other Motor Vehicle Crashes	**44**	**63.8%**
	Total	**69**	**100.0%**

A.13 Reconstruction Project along I-75 (State Line to Erie Road)

The rural freeway project shown in the map below included approximately 5.0 miles of pavement reconstruction along I-75 north of Michigan/Ohio state line. The work was completed primarily via crossovers during the 2019 and 2020 construction seasons. It should be noted that the transition and termination areas crossed the state line. Therefore, the analysis for the southern end of the corridor begins with the activity area where consistent crash data is available.



Map of I-75 (State Line to Erie Road) Reconstruction Project

Aside from the COVID-19 pandemic, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2019. Therefore, data from 2016-2018 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: I-75 (State Line to Erie Road)

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	28,954	30,174	178,069,893	126	18	3	2.4%	70.8	10.1	1.7
2017	28,954	30,174	177,583,363	101	24	3	3.0%	56.9	13.5	1.7
2018	28,603	30,312	176,598,336	120	18	4	3.3%	68.0	10.2	2.3
2019	26,905	29,268	167,913,118	233	41	113	48.5%	138.8	24.4	67.3
2020	21,517	20,640	127,733,348	127	23	54	42.5%	99.4	18.0	42.3
2021	28,690	28,258	171,606,108	82	12	5	6.1%	47.8	7.0	2.9
2022	28,214	28,760	171,060,132	104	21	14	13.5%	60.8	12.3	8.2
2023	28,950	29,545	175,602,986	167	41	85	50.9%	95.1	23.3	48.4
All Years	**27,598**	**28,391**	**1,346,167,284**	**1,060**	**198**	**281**	**26.5%**	**78.7**	**14.7**	**20.9**

The crash rate during the work period (122.6) was considerably higher compared to the rate observed for the corridor under normal operations (65.2 for the years 2016 to 2018). When compared to performance under normal operations observed during the construction season (51.6), considerable increases were observed in both rear end and sideswipe same crash rates.

Summary of Work Zone Traffic Crash and Volume Data: I-75 (State Line to Erie Road)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Stages 1-2	6/1/2019	6/30/2019	30	Single Lane Closures	13,761,653	38	6	30	78.9%	276.1	43.6	218.0
Stage 3	7/1/2019	12/21/2019	174	Crossover (NB in SB Roadbed)	80,094,245	107	20	83	77.6%	133.6	25.0	103.6
Winter 2019	12/22/2019	3/29/2020	99	All Lanes Open	34,514,669	42	6	0	0.0%	121.7	17.4	0.0
Stage 4	3/30/2020	5/23/2020	55	SB Left Lane Closure	19,186,844	15	5	10	66.7%	78.2	26.1	52.1
Stage 5	5/24/2020	10/28/2020	158	Crossover (SB in ND Roadbed)	55,118,569	53	7	39	73.6%	96.2	12.7	70.8
Stage 6	10/29/2020	11/24/2020	27	Left Lane Closures	9,418,996	5	3	5	100.0%	53.1	31.9	53.1
All Stages	**6/1/2019**	**11/24/2020**	**543**		**212,094,976**	**260**	**47**	**167**	**64.2%**	**122.6**	**22.2**	**78.7**

Crash Rates by Worst Injury/Type: I-75 (State Line to Erie Road) – *Excludes Winter Shutdown*

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.5	1.1
Severe Injury (A)	1.3	1.1
Minor Injury (B)	1.8	7.9
Possible Injury (C)	5.8	13.0
Property Damge Only	42.3	99.7
Total	**51.6**	**122.8**

Crash Type	Normal Operations	All Stages
Single Vehicle	24.3	32.7
Head On	0.0	0.6
Angle	0.0	0.0
Rear End	9.5	42.8
Sideswipe Same	12.3	40.0
Sideswipe Opposite	0.0	0.0
Other	5.5	6.8
Total	**51.6**	**122.8**

Excluding the portion of the work zone that extended into Ohio, approximately 130.0 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations. This represents an increase of approximately 100.0 percent. While Stage 3 had the largest overall impact (+64.9 crashes), Stages 1-2 had the largest relative impact on performance. This was driven by a concentration of rear end collisions related to vehicles stopping or slowing in the work zone along southbound I-75 adjacent to the interchange with Summit Street. Nearly one-third (17 out of 57) rear end collisions that were experienced over the entire project occurred during this 30-day period in June of 2019.

Total Traffic Crashes by Stage: I-75 (State Line to Erie Road)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Stages 1-2	Single Lane Closures	6/1/2019	6/30/2019	30	7.4	7.1	7.2	38.0	**+30.8**	**428.3%**
Stage 3	Crossover (NB in SB Roadbed)	7/1/2019	12/21/2019	174	43.0	41.9	42.1	107.0	**+64.9**	**154.1%**
Winter 2019	All Lanes Open	12/22/2019	3/29/2020	99	33.8	37.6	36.2	42.0	**+5.8**	**16.1%**
Stage 4	SB Left Lane Closure	3/30/2020	5/23/2020	55	10.5	10.1	10.2	15.0	**+4.8**	**46.9%**
Stage 5	Crossover (SB in ND Roadbed)	5/24/2020	10/28/2020	158	30.1	29.1	29.3	53.0	**+23.7**	**80.6%**
Stage 6	Left Lane Closures	10/29/2020	11/24/2020	27	5.1	5.0	5.0	5.0	**-0.0**	**-0.3%**
All Stages		**6/1/2019**	**11/24/2020**	**543**	**129.9**	**130.7**	**130.0**	**260.0**	**+130.0**	**100.0%**

Total Traffic Crashes by Area: I-75 (State Line to Erie Road) – *Excludes Winter Shutdown*

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
NB I-75	Activity	23,321	31.2	26.2	27.5	49.0	**+21.5**	**78.4%**
	Termination	24,738	1.3	1.0	1.1	2.0	**+0.9**	**82.8%**
	Downstream	24,287	6.0	4.5	4.9	10.0	**+5.1**	**106.2%**
All Northbound Areas		**24,115**	**38.5**	**31.7**	**33.4**	**61.0**	**+27.6**	**82.6%**
SB I-75	Upstream	24,704	6.0	5.4	5.6	7.0	**+1.4**	**25.4%**
	Advance Warning	24,166	14.1	16.7	16.1	26.0	**+9.9**	**61.9%**
	Transition	24,424	1.7	0.7	0.9	4.0	**+3.1**	**329.0%**
	Activity	23,157	35.8	38.6	37.9	120.0	**+82.1**	**216.7%**
All Soundbound Areas		**24,113**	**57.6**	**61.4**	**60.5**	**157.0**	**+96.5**	**159.7%**

In general, there were not major changes in safety performance along the ramps impacted by the work activity. However, there was also a concentration of crashes along the southbound I-75 exit ramp to Summit Road consistent with the pattern observed on the mainline noted above.

Traffic Crashes by Ramp: I-75 (State Line to Erie Road)

Ramp Information			Average	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.	AADT	Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
Summit St NB Entrance Ramp	0.229	NB	1,629	1,096	0	0	543	0	0	0.000	0.000
NB Summit St Exit Ramp	0.620	NB	1,530	1,096	4	1	469	1	1	0.004	0.002
NB Erie Rd Exit Ramp	0.443	NB	120	1,096	1	0	466	0	0	0.001	0.000
Erie Rd NB Entrance Ramp	0.172	NB	412	1,096	0	0	484	1	1	0.000	0.002
NB Luna Pier Rd Exit Ramp	0.388	NB	1,059	1,096	2	0	543	3	0	0.002	0.006
Luna Pier Rd NB Entrance Ramp	0.310	NB	2,034	1,096	1	0	543	0	0	0.001	0.000
SB Luna Pier Rd Exit Ramp	0.418	SB	1,969	1,096	4	0	543	2	1	0.004	0.004
Luna Pier Rd SB Entrance Ramp	0.256	SB	934	1,096	1	0	543	0	0	0.001	0.000
SB Erie Rd Exit Ramp	0.396	SB	410	1,096	6	0	466	0	0	0.005	0.000
Erie Rd SB Entrance Ramp	0.274	SB	112	1,096	0	0	484	0	0	0.000	0.000
Summit St SB Entrance Ramp	0.371	SB	1,896	1,096	3	1	543	2	1	0.003	0.004
SB Summit Rd Exit Ramp	0.650	SB	1,401	1,096	2	0	469	4	3	0.002	0.009
All Ramps	**4.528**	**-**	**1,126**	**13,152**	**24**	**2**	**6,096**	**13**	**7**	**0.002**	**0.002**

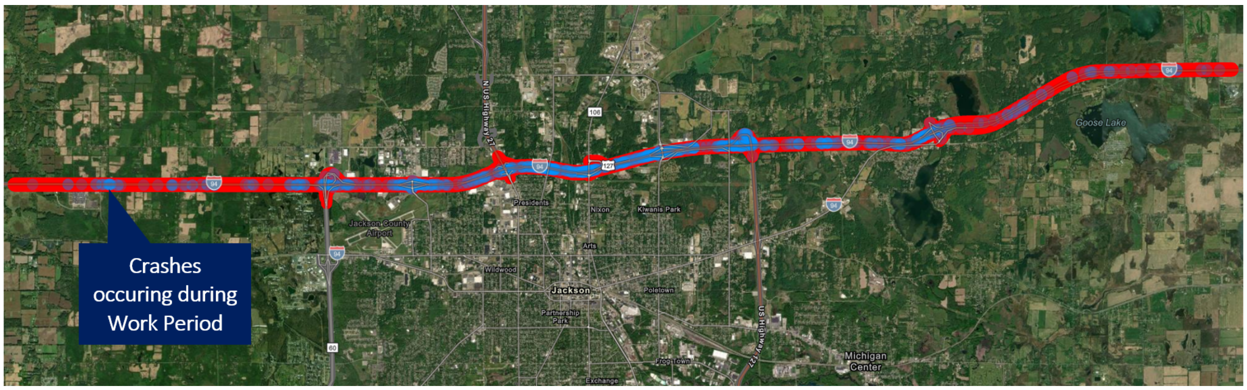
Given the review of each UD-10 crash report form diagram and narrative, the most common circumstance directly related to work zone temporary traffic control was rear end collisions related to vehicles stopping or slowing.

Work Zone Traffic Crashes by Circumstance: I-75 (State Line to Erie Road)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	2	0.7%
	Vehicle(s) Struck Channelizing Devices	6	2.2%
	Sideswipe Same Collisions Related to Lane Closure	2	0.7%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	57	20.9%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	6	2.2%
	Vehicle(s) Entered Work Area	0	0.0%
	Collisions involving Work Vehicles	3	1.1%
	Collisions involving Workers	0	0.0%
	Other Work Zone Related Motor Vehicle Crashes	11	4.0%
	All Motor Vehicle Crashes Directly Related to Work Zone	**87**	**31.9%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	56	20.5%
	Other Sideswipe Same Collisions	61	22.3%
	Other Rear End Collisions	21	7.7%
	Rear End Collisions at Ramp Termini	1	0.4%
	Vehicles Striking Loose Objects on Roadway	23	8.4%
	Vehicles Struck Pedestrian on Freeway	0	0.0%
	Vehicles Struck Pedestrian at Ramp Termini	0	0.0%
	Vehicles Struck Bicyclist at Ramp Termini	0	0.0%
	Other Motor Vehicle Crashes	24	8.8%
	All Other Motor Vehicle Crashes	**186**	**68.1%**
	Total	**273**	**100.0%**

A.14 Reconstruction Project along I-94 (Blackman Road to Sargent Road)

The suburban freeway project shown in the map below included approximately ten miles of reconstruction work along I-94 as it runs north of Jackson, Michigan. The work was completed primarily via a series of crossovers and split merge configurations from 2018 to 2020. A dynamic stopped traffic advisory system was also employed as a part of the project. It should also be noted that there were limitations in identifying the timing of specific stages and associated temporary traffic control configurations. This primarily impacted the ability to determine (1) the staging within each construction season and (2) the location of transition and termination areas.



Map of I-94 (Blackman Road to Sargent Road) Reconstruction Project

There was no work activity prior to the implementation of work zone temporary traffic control in 2018. Therefore, data from 2016 and 2017 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: I-94 (Blackman Road to Sargent Road)

Year	Average EB AADT	Average WB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	24,298	26,755	266,987,924	219	42	22	10.0%	82.0	15.7	8.2
2017	24,298	26,755	266,258,448	318	48	8	2.5%	119.4	18.0	3.0
2018	24,325	26,843	266,924,178	274	42	68	24.8%	102.7	15.7	25.5
2019	25,475	27,996	278,911,135	319	45	180	56.4%	114.4	16.1	64.5
2020	20,832	20,788	217,511,586	186	20	80	43.0%	85.5	9.2	36.8
2021	24,769	24,751	257,913,204	240	39	80	33.3%	93.1	15.1	31.0
2022	24,768	24,675	257,958,297	229	45	94	41.0%	88.8	17.4	36.4
2023	24,729	25,234	262,076,811	238	38	100	42.0%	90.8	14.5	38.2
All Years	24,187	25,475	2,074,541,584	2,023	319	632	31.2%	97.5	15.4	30.5

Traffic crash rates during the work period across the entire corridor (106.3) were similar to what is typically observed during a typical year with no construction activity (100.7 for the years 2016 to 2017). The crash rate observed during a typical construction-season along this corridor is similar (101.0), where the corridor experienced larger rates of sideswipe same collisions during work activity with lower rates of rear end collisions.

Summary of Work Zone Traffic Crash and Volume Data: I-94 (Blackman Road to Sargent Road)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Construction 2018	7/13/2018	11/14/2018	125	Reconstruction Work	91,412,390	97	10	53	54.6%	106.1	10.9	58.0
Winter 2018	11/15/2018	3/11/2019	117	All Lanes Open	89,404,391	92	9	22	23.9%	102.9	10.1	24.6
Construction 2019	3/12/2019	12/31/2019	295	Reconstruction Work	226,306,328	263	40	172	65.4%	116.2	17.7	76.0
Construction 2020	1/1/2020	9/19/2020	263	Reconstruction Work	156,299,309	147	14	77	52.4%	94.1	9.0	49.3
All Stages	**7/13/2018**	**9/19/2020**	**800**		**563,422,418**	**599**	**73**	**324**	**54.1%**	**106.3**	**13.0**	**57.5**

Crash Rates by Worst Injury/Type: I-94 (Blackman Rd. - Sargent Rd.) - *Excludes Winter Shutdown*

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.5	0.9
Severe Injury (A)	1.3	1.4
Minor Injury (B)	3.3	2.5
Possible Injury (C)	13.0	6.6
Property Damge Only	83.0	78.6
Total	**101.0**	**90.0**

Crash Type	Normal Operations	All Stages
Single Vehicle	35.0	35.0
Head On	0.5	0.0
Angle	0.3	0.0
Rear End	39.3	22.0
Sideswipe Same	20.0	27.0
Sideswipe Opposite	0.0	0.2
Other	6.0	5.9
Total	**101.0**	**90.0**

Overall, approximately 28.5 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations. This represents an increase of approximately 5.0 percent. These increases were driven by degraded performance within the westbound activity area.

Total Traffic Crashes by Stage: I-94 (Blackman Road to Sargent Road)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Construction 2018	Reconstruction Work	7/13/2018	11/14/2018	125	73.0	94.0	90.8	97.0	+6.2	6.9%
Winter 2018	All Lanes Open	11/15/2018	3/11/2019	117	125.6	89.7	104.3	92.0	-12.3	-11.8%
Construction 2019	Reconstruction Work	3/12/2019	12/31/2019	295	187.8	233.5	227.9	263.0	+35.1	15.4%
Construction 2020	Reconstruction Work	1/1/2020	9/19/2020	263	104.3	162.0	147.6	147.0	-0.6	-0.4%
All Stages		**7/13/2018**	**9/19/2020**	**800**	**490.7**	**579.2**	**570.5**	**599.0**	**+28.5**	**5.0%**

Total Crashes by Area: I-94 (Blackman Rd. to Sargent Rd.) – *Excludes Winter Shutdown*

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
I-94 EB	Upstream	18,146	9.3	14.8	12.5	8.0	-4.5	-36.1%
	Advance Warning	16,744	12.1	12.4	12.2	20.0	+7.8	63.5%
	Activity	24,219	133.8	209.6	192.4	179.0	-13.4	-7.0%
	Downstream	23,870	12.5	6.1	7.8	2.0	-5.8	-74.4%
All Eastbound Areas		**20,745**	**167.6**	**242.9**	**225.0**	**209.0**	**-16.0**	**-7.1%**
I-94 WB	Upstream	22,588	10.9	0.0	3.4	7.0	+3.6	107.5%
	Advance Warning	22,588	32.1	18.7	22.8	22.0	-0.8	-3.5%
	Activity	25,537	147.1	225.7	210.8	265.0	+54.2	25.7%
	Downstream	18,014	7.5	2.2	4.3	4.0	-0.3	-6.4%
All Westbound Areas		**22,182**	**197.5**	**246.7**	**241.3**	**298.0**	**+56.7**	**23.5%**

In general, there were not major changes in safety performance along the ramps impacted by the work. However, there was a pattern of rear end collisions along the westbound entrance ramp from US-127 that was not present during normal operations. Given the review of each UD-10 report form diagram and narrative, the most common circumstance directly related to work zone temporary traffic control was rear end collisions related to vehicles stopping or slowing.

Traffic Crashes by Ramp: I-94 (Blackman Road to Sargent Road)

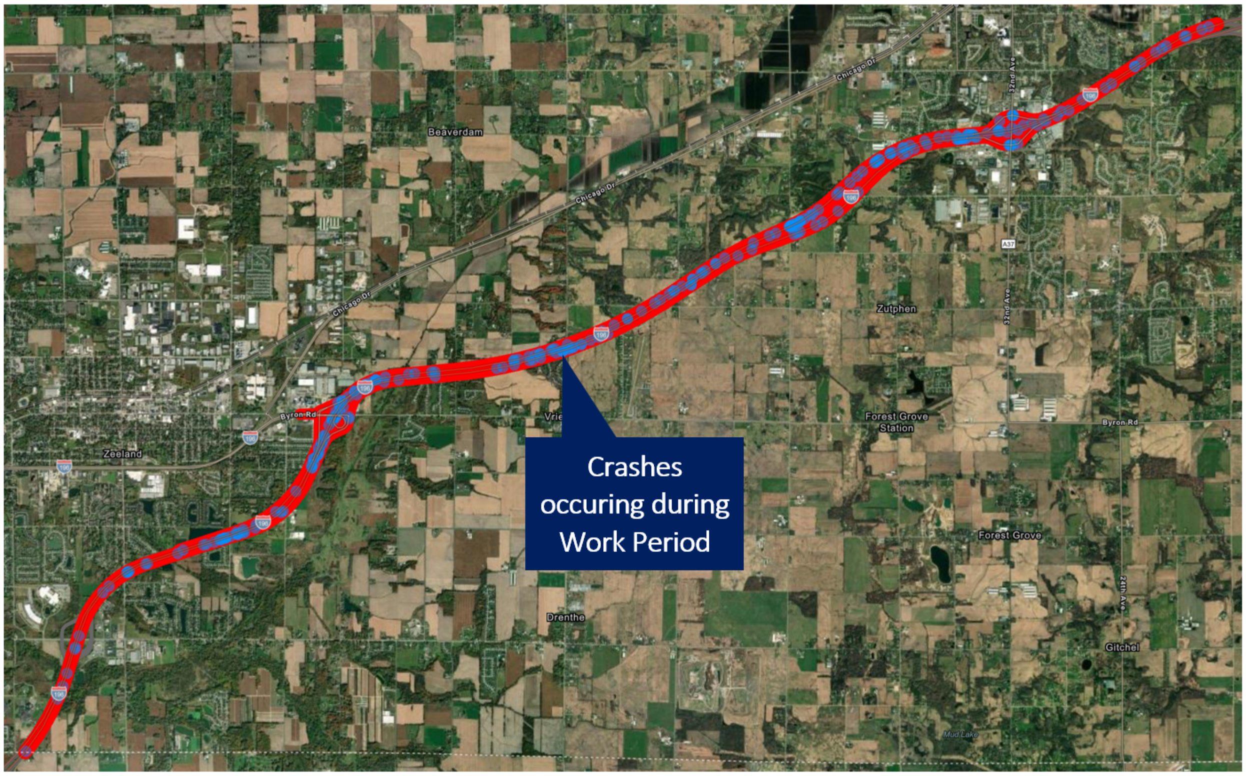
Ramp Information			Average	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.	AADT	Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
EB Exit Ramp to M-60	0.319	EB	676	731	0	0	810	0	0	0.000	0.000
M-60 EB Entrance Ramp	0.342	EB	6,035	731	1	0	810	1	1	0.001	0.001
EB Exit Ramp to Airport Rd	0.187	EB	3,429	731	8	0	810	5	1	0.011	0.006
Airport Rd EB Entrance Ramp	0.177	EB	4,495	731	2	0	810	1	0	0.003	0.001
EB Exit Ramp to Cooper St	0.152	EB	3,674	731	0	0	810	0	0	0.000	0.000
Cooper St EB Entrance Ramp	0.233	EB	1,722	731	0	0	810	0	0	0.000	0.000
EB Exit Ramp to Elm Ave	0.117	EB	2,299	731	1	0	810	4	1	0.001	0.005
Elm Ave EB Entrance Ramp	0.207	EB	2,934	731	3	0	810	0	0	0.004	0.000
EB Exit Ramp to US-127s	0.227	EB	10,789	731	8	0	810	3	0	0.011	0.004
US-127s EB Entrance Ramp	0.227	EB	3,842	731	3	0	810	1	0	0.004	0.001
EB Exit Ramp to Sargent Rd	0.290	EB	2,065	731	5	0	810	3	1	0.007	0.004
Sargent Rd EB Entrance Ramp	0.397	EB	1,630	731	0	0	810	0	0	0.000	0.000
WB Exit Ramp to Sargent Rd	0.217	WB	2,372	731	8	0	810	1	0	0.011	0.001
Sargent Rd WB Entrance Ramp	0.167	WB	1,680	731	1	0	810	0	0	0.001	0.000
US-127s WB Entrance Ramp	0.485	WB	10,750	731	8	0	810	19	1	0.011	0.023
WB Exit Ramp to US-127s	0.402	WB	3,777	731	12	0	810	6	3	0.016	0.007
WB Exit Ramp to Elm Ave	0.177	WB	3,217	731	4	0	810	3	0	0.005	0.004
Elm Ave WB Entrance Ramp	0.109	WB	2,288	731	1	0	810	0	0	0.001	0.000
WB Exit Ramp to Cooper St	0.563	WB	1,668	731	0	0	810	0	0	0.000	0.000
Cooper St WB Entrance Ramp	0.398	WB	2,954	731	0	0	810	0	0	0.000	0.000
WB Exit Ramp to Airport Rd	0.377	WB	4,937	731	3	0	810	4	1	0.004	0.005
Airport Rd WB Entrance Ramp	0.146	WB	3,696	731	5	0	810	1	0	0.007	0.001
WB Exit Ramp to M-60	0.511	WB	5,804	731	1	0	810	4	1	0.001	0.005
M-60 WB Entrance Ramp	0.392	WB	610	731	2	0	810	0	0	0.003	0.000
All Ramps	**6.820**	**-**	**3,639**	**17,544**	**76**	**0**	**19,440**	**56**	**10**	**0.004**	**0.003**

Work Zone Traffic Crashes by Circumstance: I-94 (Blackman Road to Sargent Road)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	5	0.8%
	Vehicle(s) Struck Channelizing Devices	20	3.1%
	Sideswipe Same Collisions Related to Lane Closure	2	0.3%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	80	12.2%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	4	0.6%
	Vehicle(s) Entered Work Area	1	0.2%
	Collisions involving Work Vehicles	2	0.3%
	Collisions involving Workers	0	0.0%
	Other Work Zone Related Motor Vehicle Crashes	23	3.5%
	All Motor Vehicle Crashes Directly Related to Work Zone	**137**	**20.9%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	193	29.5%
	Other Sideswipe Same Collisions	149	22.8%
	Other Rear End Collisions	69	10.6%
	Rear End Collisions at Ramp Termini	10	1.5%
	Vehicles Striking Loose Objects on Roadway	41	6.3%
	Vehicles Struck Pedestrian on Freeway	1	0.2%
	Vehicles Struck Pedestrian at Ramp Termini	0	0.0%
	Vehicles Struck Bicyclist at Ramp Termini	0	0.0%
	Other Motor Vehicle Crashes	54	8.3%
	All Other Motor Vehicle Crashes	**517**	**79.1%**
	Total	**654**	**100.0%**

A.15 Reconstruction Project along I-196 (Byron Road to 32nd Avenue)

The suburban freeway project shown in the map below included approximately 6.8 miles of reconstruction work along I-96 east of Holland, Michigan. The work was primarily completed via crossovers during the 2022 and 2023 construction seasons.



Map of I-196 (Byron Road to 32nd Avenue) Reconstruction Project

In addition to the 2020 COVID-19 pandemic, prior construction was also present during 2018 and 2019. Therefore, data from 2016-2017 and 2021 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: I-196 (Byron Road to 32nd Avenue)

Year	Average EB AADT	Average WB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	22,277	23,478	200,123,005	156	26	2	1.3%	78.0	13.0	1.0
2017	22,252	23,478	199,326,814	150	17	1	0.7%	75.3	8.5	0.5
2018	22,408	23,642	200,722,030	166	21	26	15.7%	82.7	10.5	13.0
2019	22,102	26,581	204,790,599	128	17	12	9.4%	62.5	8.3	5.9
2020	18,731	19,475	165,316,071	73	12	17	23.3%	44.2	7.3	10.3
2021	21,844	23,926	197,038,655	90	16	7	7.8%	45.7	8.1	3.6
2022	21,259	25,566	199,458,271	144	18	48	33.3%	72.2	9.0	24.1
2023	21,913	26,333	205,407,054	130	21	77	59.2%	63.3	10.2	37.5
All Years	21,598	24,060	1,572,182,500	1,037	148	190	18.3%	66.0	9.4	12.1

Traffic crash rates during the work period across the entire corridor (65.7) were similar to what is typically observed during a typical year with no construction activity (66.4 for the years 2016 to 2017 and 2021). The crash rate observed during a typical construction-season under normal operations along this corridor were slightly lower (58.6).

Summary of Work Zone Crash and Volume Data: I-196 (Byron Road to 32nd Avenue)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
PreStage and Tree Clearing	3/7/2022	4/19/2022	44	Pre-Stage Work	25,078,493	12	0	0	0.0%	47.8	0.0	0.0
Stage 1	4/20/2022	11/28/2022	223	Crossover (WB in EB Roadbed)	125,687,903	79	13	48	60.8%	62.9	10.3	38.2
Winter 2022	11/29/2022	4/1/2023	124	All Lanes Open	72,755,761	44	5	1	2.3%	60.5	6.9	1.4
Stage 2	4/2/2023	10/8/2023	190	Crossover (EB in WB Roadbed)	109,611,923	76	15	58	76.3%	69.3	13.7	52.9
Stage 3	10/9/2023	11/6/2023	29	Single Lane Closures	17,014,300	19	0	16	84.2%	111.7	0.0	94.0
All Stages	**3/7/2022**	**11/6/2023**	**610**		**350,148,379**	**230**	**33**	**123**	**53.5%**	**65.7**	**9.4**	**35.1**

Crash Rates by Worst Injury/Type: I-196 (Byron Rd. to 32nd Ave.) – *Excludes Winter Shutdown*

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.2	0.0
Severe Injury (A)	0.9	1.8
Minor Injury (B)	2.2	1.8
Possible Injury (C)	6.5	6.5
Property Damge Only	48.7	57.0
Total	**58.6**	**67.1**

Crash Type	Normal Operations	All Stages
Single Vehicle	23.9	29.6
Head On	0.2	0.0
Angle	0.4	0.0
Rear End	14.5	14.4
Sideswipe Same	13.2	17.3
Sideswipe Opposite	0.2	0.0
Other	6.0	5.8
Total	**58.6**	**67.1**

On the aggregate, there was not a considerable impact on expected safety performance along the corridor during the work period. However, it is worth noting the degraded performance within the westbound transition and activity area as well as the eastbound advance warning area. The single lane closures employed as a part of the third stage resulted in the largest relative increase in motor vehicle crashes.

In general, there were not major changes in performance along the ramps impacted by the work. Given the review of each UD-10 report form diagram and narrative, the most common circumstance directly related to work zone temporary traffic control was rear end collisions related to vehicles stopping or slowing.

Total Traffic Crashes by Stage: I-196 (Byron Road to 32nd Avenue)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
PreStage and Tree Clearing	Pre-Stage Work	3/7/2022	4/19/2022	44	13.5	15.8	15.3	12.0	-3.3	-21.5%
Stage 1	Crossover (WB in EB Roadbed)	4/20/2022	11/28/2022	223	67.9	79.9	77.3	79.0	+1.7	2.2%
Winter 2022	All Lanes Open	11/29/2022	4/1/2023	124	66.7	70.1	69.0	44.0	-25.0	-36.3%
Stage 2	Crossover (EB in WB Roadbed)	4/2/2023	10/8/2023	190	59.2	69.9	67.5	76.0	+8.5	12.6%
Stage 3	Single Lane Closures	10/9/2023	11/6/2023	29	9.2	10.7	10.4	19.0	+8.6	83.5%
All Stages		**3/7/2022**	**11/6/2023**	**610**	**216.5**	**246.3**	**239.5**	**230.0**	**-9.5**	**-4.0%**

Total Crashes by Area: I-196 (Byron Road to 32nd Avenue) – *Excludes Winter Shutdown*

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
I-196 EB	Upstream	13,897	1.9	1.2	1.4	1.0	-0.4	-30.5%
	Advance Warning	16,834	10.8	11.0	10.9	20.0	+9.1	83.0%
	Transition	16,834	1.5	2.7	2.4	4.0	+1.6	68.7%
	Activity	22,051	46.6	43.4	44.3	44.0	-0.3	-0.7%
	Termination	24,660	2.4	1.8	2.0	1.0	-1.0	-49.6%
	Downstream	30,954	9.3	10.7	10.4	6.0	-4.4	-42.4%
All Eastbound Areas		**20,871**	**72.6**	**70.9**	**71.5**	**76.0**	**+4.5**	**6.4%**
I-196 WB	Upstream	33,006	8.5	9.9	9.7	7.0	-2.7	-27.6%
	Advance Warning	33,016	9.1	16.3	14.9	5.0	-9.9	-66.4%
	Transition	28,655	4.4	4.1	4.2	11.0	+6.8	164.6%
	Activity	27,172	47.3	67.1	62.6	80.0	+17.4	27.8%
	Termination	27,172	3.3	1.8	2.1	4.0	+1.9	90.5%
	Downstream	17,661	4.7	6.0	5.6	3.0	-2.6	-46.6%
All Eastbound Areas		**27,780**	**77.2**	**105.3**	**99.0**	**110.0**	**+11.0**	**11.1%**

Traffic Crashes by Ramp: I-196 (Byron Road to 32nd Avenue)

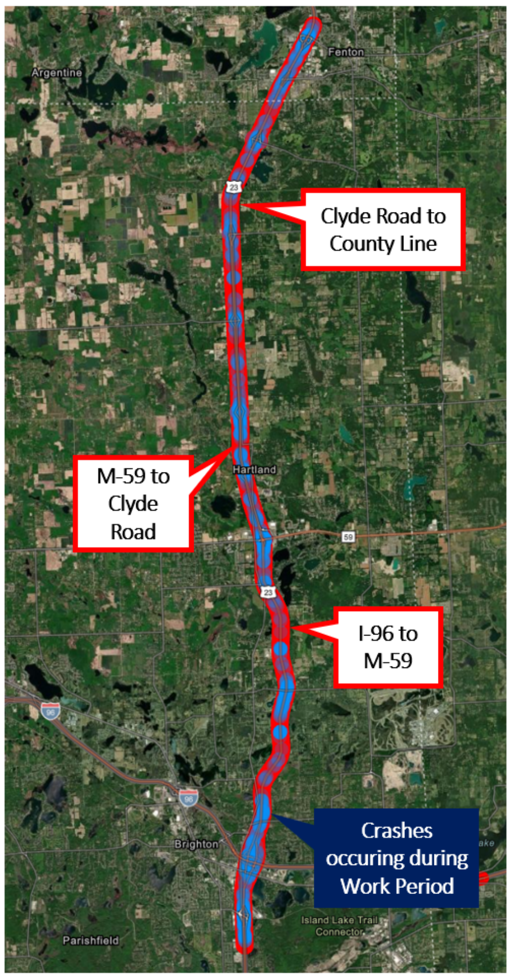
Ramp Information			Average AADT	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.		Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
EB Exit to Byron Rd	0.468	EB	2,924	1,096	6	0	502	4	2	0.005	0.008
EB Bryon Rd EB Entrance Ramp	0.269	EB	10,038	1,096	17	1	197	0	0	0.016	0.000
WB Bryon Rd EB Entrance Ramp	0.294	EB	226	1,096	7	2	197	0	0	0.006	0.000
EB Exit Ramp to 32nd Ave	0.393	EB	2,369	1,096	8	0	610	4	0	0.007	0.007
32nd Ave EB Entrance Ramp	0.427	EB	7,968	1,096	4	0	610	3	0	0.004	0.005
WB Exit Ramp to 32nd Ave	0.384	WB	7,895	1,096	24	0	610	4	0	0.022	0.007
32nd Ave WB Entrance Ramp	0.371	WB	2,798	1,096	3	0	610	1	1	0.003	0.002
WB Exit Ramp to Byron Rd	0.531	WB	6,115	1,096	15	0	574	4	3	0.014	0.007
Bryon Rd WB Entrance Ramp	0.374	WB	2,112	1,096	6	0	387	0	0	0.005	0.000
All Ramps	**3.511**	**-**	**4,716**	**9,864**	**90**	**3**	**4,297**	**20**	**6**	**0.009**	**0.005**

Work Zone Traffic Crashes by Circumstance: I-196 (Byron Road to 32nd Avenue)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	0	0.0%
	Vehicle(s) Struck Channelizing Devices	7	2.8%
	Sideswipe Same Collisions Related to Lane Closure	9	3.6%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	31	12.4%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	10	4.0%
	Vehicle(s) Entered Work Area	1	0.4%
	Collisions involving Work Vehicles	0	0.0%
	Collisions involving Workers	1	0.4%
	Other Work Zone Related Motor Vehicle Crashes	22	8.8%
	All Motor Vehicle Crashes Directly Related to Work Zone	**81**	**32.4%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	78	31.2%
	Other Sideswipe Same Collisions	41	16.4%
	Other Rear End Collisions	15	6.0%
	Rear End Collisions at Ramp Termini	9	3.6%
	Vehicles Striking Loose Objects on Roadway	10	4.0%
	Vehicles Struck Pedestrian on Freeway	0	0.0%
	Vehicles Struck Pedestrian at Ramp Termini	0	0.0%
	Vehicles Struck Bicyclist at Ramp Termini	0	0.0%
	Other Motor Vehicle Crashes	16	6.4%
	All Other Motor Vehicle Crashes	**169**	**67.6%**
	Total	**250**	**100.0%**

A.16 Resurfacing Project along US-23 (I-96 to Livingston County Line)

The suburban freeway project shown in the map below included approximately 8.0 miles of resurfacing work along US-23 between Brighton and Flint, Michigan. The work was completed in three segments during the 2022 and 2023 construction seasons. While a range of traffic control configurations were employed, it is worth noting that the project included a period with a full closure and nightly detour. It should also be noted that there were limitations in identifying the timing of specific stages and associated temporary traffic control configurations. This primarily impacted the ability to disaggregate the project beyond the analysis of each segment.



Map of US-23 (I-96 to Livingston County Line) Resurfacing Project

Aside from the COVID-19 pandemic and unrelated construction in 2021, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2022. Therefore, data from 2016 to 2019 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: US-23 (I-96 to Livingston County Line)

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	28,045	28,507	466,768,523	414	66	18	4.3%	88.7	14.1	3.9
2017	28,045	28,507	465,493,199	460	80	26	5.7%	98.8	17.2	5.6
2018	29,288	29,895	480,530,030	492	77	4	0.8%	102.4	16.0	0.8
2019	29,326	29,743	486,171,523	531	68	0	0.0%	109.2	14.0	0.0
2020	24,535	24,307	408,264,796	276	60	1	0.4%	67.6	14.7	0.2
2021	26,437	25,998	441,185,630	374	69	37	9.9%	84.8	15.6	8.4
2022	27,156	26,521	447,352,508	358	56	38	10.6%	80.0	12.5	8.5
2023	27,560	27,327	453,093,891	482	71	150	31.1%	106.4	15.7	33.1
All Years	**27,549**	**27,600**	**3,648,860,102**	**3,387**	**547**	**274**	**8.1%**	**92.8**	**15.0**	**7.5**

Traffic crash rates during the work period across the entire corridor (96.3) were similar to what is typically observed during a typical year with no construction activity (99.9 for the years 2016 to 2019). Additionally, the crash rate observed during a typical construction-season along this corridor (85.2) is consistent with the performance observed along the corridor when the winter shutdown period is excluded (86.5).

Summary of Work Zone Crash and Volume Data: US-23 (I-96 to Livingston County Line)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
All Stages	5/23/2022	9/10/2023	476	Resurfacing Work	585,796,072	564	85	122	21.6%	96.3	14.5	20.8
All Stages	**5/23/2022**	**9/10/2023**	**476**		**585,796,072**	**564**	**85**	**122**	**21.6%**	**96.3**	**14.5**	**20.8**

Traffic Crash Rates by Worst Injury and Type: US-23 (I-96 to Livingston County Line)

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.3	0.3
Severe Injury (A)	1.3	1.0
Minor Injury (B)	4.0	4.4
Possible Injury (C)	8.8	7.5
Property Damge Only	70.8	73.2
Total	**85.2**	**86.5**

Crash Type	Normal Operations	All Stages
Single Vehicle	28.6	28.3
Head On	0.2	0.3
Angle	0.7	0.2
Rear End	37.4	38.6
Sideswipe Same	15.9	16.9
Sideswipe Opposite	0.0	0.2
Other	2.4	2.0
Total	**85.2**	**86.5**

On the aggregate, there was not a considerable impact on expected safety performance along the corridor during the work period. However, performance varied along the corridor consistent with the temporary traffic control configuration employed.

Total Traffic Crashes by Stage: US-23 (I-96 to Livingston County Line)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
All Stages	Resurfacing Work	5/23/2022	9/10/2023	476	603.4	560.4	569.3	564.0	-5.3	-0.9%
All Stages		**5/23/2022**	**9/10/2023**	**476**	**603.4**	**560.4**	**569.3**	**564.0**	**-5.3**	**-0.9%**

Total Traffic Crashes by Area: US-23 (I-96 to Livingston County Line)

Section			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Segment	Length	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
NB US-23	Upstream	2.00	46.4	79.3	77.5	95.0	+17.5	22.6%
	I-96 to M-59	7.86	105.3	63.1	70.1	80.0	+9.9	14.2%
	M-59 to Clyde Road	3.01	39.7	42.9	42.4	46.0	+3.6	8.6%
	Clyde to County Line	7.51	91.4	80.2	81.2	51.0	-30.2	-37.2%
	Downstream	2.00	19.5	38.0	35.5	21.0	-14.5	-40.9%
All Northbound Sections		**22.38**	**302.3**	**303.5**	**306.6**	**293.0**	**-13.6**	**-4.4%**
SB US-23	Upstream	2.00	21.5	52.9	49.4	36.0	-13.4	-27.2%
	Clyde to County Line	7.51	94.4	72.4	76.7	103.0	+26.3	34.3%
	M-59 to Clyde Road	3.01	39.8	34.7	35.6	34.0	-1.6	-4.4%
	I-96 to M-59	7.86	95.5	68.9	71.8	50.0	-21.8	-30.4%
	Downstream	2.00	49.9	28.0	29.1	48.0	+18.9	64.8%
All Southbound Sections		**22.38**	**301.1**	**256.9**	**262.6**	**271.0**	**+8.4**	**3.2%**

The areas where intermittent lane and shoulder closures were in place represented the largest impact on performance. The periods with nightly detours and lane closures experienced fewer crashes than expected without the work zone present. However, it should be noted that traffic volume data specific to these periods only (where daily volumes are likely decreased) were not available and therefore these estimates should be interpreted with caution. In general, there were not major changes in safety performance along the ramps impacted by the work activity.

Total Traffic Crashes by Type of Activity: US-23 (I-96 to Livingston County Line)

Type of Activity	VMT	Crashes during Normal Operations			Crashes during Work Zone Operations		
		Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Intermittent Lane and Shoulder Closures	158,803,259	137.2	114.8	117.7	156.0	+38.3	32.5%
Lane and Shoulder Closures with Nightly Detour	17,013,339	14.3	11.9	12.2	5.0	-7.2	-59.1%
Crossover (Unsure on Side)	38,228,151	32.4	25.3	26.2	33.0	+6.8	25.7%
Nightly Lane Closures	34,073,779	28.4	22.3	23.0	13.0	-10.0	-43.5%

Traffic Crashes by Ramp: US-23 (I-96 to Livingston County Line)

Ramp Information			Average AADT	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.		Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
NB Exit Ramp to M-59	0.379	NB	5,390	1,461	45	0	476	15	1	0.031	0.032
M-59 NB Entrance Ramp	0.348	NB	5,909	1,461	26	1	476	10	0	0.018	0.021
NB Exit Ramp to Clyde Rd	0.212	NB	2,394	1,461	1	0	476	2	0	0.001	0.004
Clyde Rd NB Entrance Ramp	0.234	NB	1,777	1,461	2	0	476	0	0	0.001	0.000
NB Exit Ramp to Center Rd	0.251	NB	1,003	1,461	4	0	476	1	0	0.003	0.002
Center Rd NB Entrance Ramp	0.254	NB	1,655	1,461	0	0	476	0	0	0.000	0.000
NB Exit Ramp to White Lake Rd	0.182	NB	1,587	1,461	5	0	476	2	0	0.003	0.004
White Lake Rd NB Entrance Ramp	0.295	NB	2,443	1,461	1	0	476	0	0	0.001	0.000
SB Exit Ramp to White Lake Rd	0.265	SB	2,272	1,461	5	0	476	2	0	0.003	0.004
White Lake Rd SB Entrance Ramp	0.174	SB	1,647	1,461	7	0	476	0	0	0.005	0.000
SB Exit Ramp to Center Rd	0.208	SB	1,645	1,461	0	0	476	2	0	0.000	0.004
Center Rd SB Entrance Ramp	0.213	SB	977	1,461	1	0	476	0	0	0.001	0.000
SB Exit Ramp to Clyde Rd	0.228	SB	1,613	1,461	3	0	476	5	0	0.002	0.011
Clyde Rd SB Entrance Ramp	0.242	SB	2,429	1,461	1	0	476	1	1	0.001	0.002
SB Exit Ramp to M-59	0.374	SB	5,557	1,461	22	0	476	4	0	0.015	0.008
M-59 SB Entrance Ramp	0.325	SB	5,845	1,461	11	0	476	1	0	0.008	0.002
All Ramps	**4.183**	**-**	**2,759**	**23,376**	**134**	**1**	**7,616**	**45**	**2**	**0.006**	**0.006**

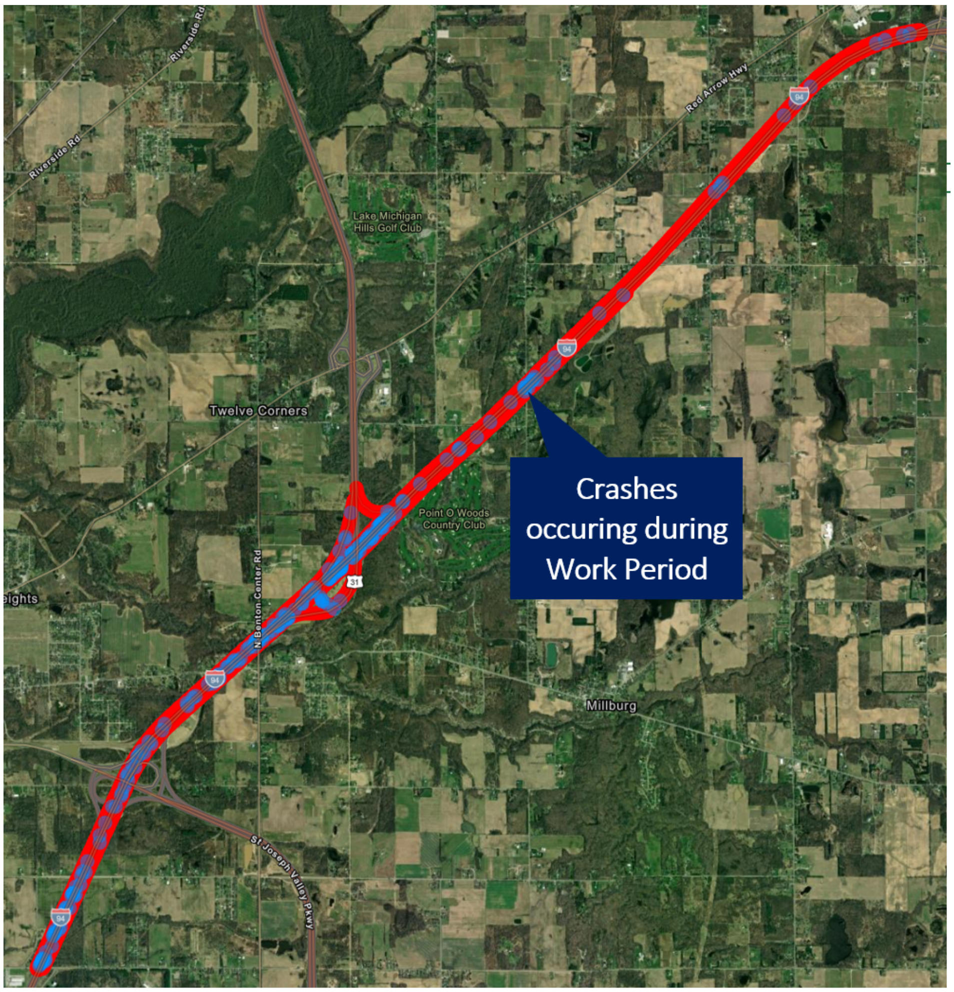
Given the review of each UD-10 crash report form diagram and narrative, the most common circumstance directly related to work zone temporary traffic control was rear end collisions related to vehicles stopping or slowing.

Work Zone Traffic Crashes by Circumstance: US-23 (I-96 to Livingston County Line)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	4	0.7%
	Vehicle(s) Struck Channelizing Devices	9	1.5%
	Sideswipe Same Collisions Related to Lane Closure	0	0.0%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	76	12.5%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	4	0.7%
	Vehicle(s) Entered Work Area	0	0.0%
	Collisions involving Work Vehicles	1	0.2%
	Collisions involving Workers	0	0.0%
	Other Work Zone Related Motor Vehicle Crashes	3	0.5%
	All Motor Vehicle Crashes Directly Related to Work Zone	**97**	**15.9%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	173	28.4%
	Other Sideswipe Same Collisions	108	17.7%
	Other Rear End Collisions	158	25.9%
	Rear End Collisions at Ramp Termini	17	2.8%
	Vehicles Striking Loose Objects on Roadway	14	2.3%
	Vehicles Struck Pedestrian on Freeway	0	0.0%
	Vehicles Struck Pedestrian at Ramp Termini	2	0.3%
	Vehicles Struck Bicyclist at Ramp Termini	0	0.0%
	Other Motor Vehicle Crashes	40	6.6%
	All Other Motor Vehicle Crashes	**512**	**84.1%**
	Total	**609**	**100.0%**

A.17 Reconstruction Project along I-94 (Britain Avenue to I-196 Interchange)

The project shown in the map below included approximately 8.2 miles of reconstruction work along I-94 east of Benton Harbor, Michigan. While this project was completed with a series of crossovers during the 2021 and 2022 construction seasons, it is important to note that an adjacent project was also occurring along I-94 southwest of the study project during the same period. Therefore, the analysis of this project begins at the southwest boundary of the activity area to minimize the impact of the adjacent construction. A dynamic stopped traffic advisory system was also employed as a part of the project.



Map of I-94 (Britain Avenue to I-196 Interchange) Reconstruction Project

Aside from the COVID-19 pandemic, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2021. Therefore, data from 2016-2019 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: I-94 (Britain Avenue to I-196 Interchange)

Year	Average EB AADT	Average WB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	26,752	27,024	114,849,987	95	12	1	1.1%	82.7	10.4	0.9
2017	26,752	27,024	114,536,189	99	12	1	1.0%	86.4	10.5	0.9
2018	25,340	29,064	116,914,493	85	11	1	1.2%	72.7	9.4	0.9
2019	29,118	29,519	122,481,416	95	17	1	1.1%	77.6	13.9	0.8
2020	27,603	27,540	113,796,846	44	7	5	11.4%	38.7	6.2	4.4
2021	29,041	28,985	121,317,061	97	18	57	58.8%	80.0	14.8	47.0
2022	30,563	30,514	126,864,270	125	22	56	44.8%	98.5	17.3	44.1
2023	31,257	30,319	128,268,852	51	9	18	35.3%	39.8	7.0	14.0
All Years	**28,303**	**28,749**	**959,029,113**	**691**	**108**	**140**	**20.3%**	**72.1**	**11.3**	**14.6**

The crash rate during the work period (90.8) was considerably higher compared to the rate observed for the corridor under normal operations (79.8 for the years 2016 to 2019). When compared to performance under normal operations observed during the construction season (56.0), increases were observed in single vehicle, rear end and sideswipe same crash rates.

Summary of Work Zone Crash and Volume Data: I-94 (Britain Avenue to I-196 Interchange)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Construction 2021	4/22/2021	12/6/2021	229	Reconstruction Work	76,113,991	71	12	57	80.3%	93.3	15.8	74.9
Winter 2021	12/7/2021	4/6/2022	121	All Lanes Open	42,056,374	28	8	0	0.0%	66.6	19.0	0.0
Construction 2022	4/7/2022	11/19/2022	227	Reconstruction Work	78,899,149	80	12	56	70.0%	101.4	15.2	71.0
All Stages	**4/22/2021**	**11/19/2022**	**577**		**197,069,515**	**179**	**32**	**113**	**63.1%**	**90.8**	**16.2**	**57.3**

Crash Rates by Worst Injury/Type: I-94 (Britain Ave. to I-196 Interchange) – *Excludes Winter Shutdown*

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.6	0.0
Severe Injury (A)	0.9	0.0
Minor Injury (B)	3.4	5.2
Possible Injury (C)	4.8	10.3
Property Damge Only	46.4	81.9
Total	**56.0**	**97.4**

Crash Type	Normal Operations	All Stages
Single Vehicle	28.4	40.0
Head On	0.0	0.0
Angle	0.3	0.0
Rear End	9.7	26.4
Sideswipe Same	10.5	25.8
Sideswipe Opposite	0.0	0.0
Other	7.1	5.2
Total	**56.0**	**97.4**

Overall, approximately 20.7 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations. This represents an increase of approximately 13.1 percent. This was primarily driven by severely degraded performance along the westbound I-94 activity area.

Total Traffic Crashes by Stage: I-94 (Britain Avenue to I-196 Interchange)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Construction 2021	Reconstruction Work	4/22/2021	12/6/2021	229	65.9	44.0	47.2	71.0	+23.8	50.3%
Winter 2021	All Lanes Open	12/7/2021	4/6/2022	121	61.5	61.1	60.7	28.0	-32.7	-53.8%
Construction 2022	Reconstruction Work	4/7/2022	11/19/2022	227	72.5	47.0	50.4	80.0	+29.6	58.6%
All Stages		**4/22/2021**	**11/19/2022**	**577**	**199.9**	**152.0**	**158.3**	**179.0**	**+20.7**	**13.1%**

Total Crashes by Area: I-94 (Britain Ave. to I-196 Interchange) – *Excludes Winter Shutdown*

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
I-94 EB	Activity	29,802	54.0	37.1	38.8	55.0	+16.2	41.8%
	Downstream	21,807	7.0	4.0	4.5	2.0	-2.5	-55.9%
All Eastbound Areas		**25,804**	**61.0**	**41.1**	**43.3**	**57.0**	**+13.7**	**31.6%**
I-94 WB	Upstream	22,230	21.4	5.1	8.1	11.0	+2.9	35.5%
	Activity	29,750	56.0	44.7	46.2	83.0	+36.8	79.5%
All Westbound Areas		**25,990**	**77.4**	**49.8**	**54.4**	**94.0**	**+39.6**	**73.0%**

The 20 traffic crashes that occurred along the ramps associated with the I-196 interchange represented a modest increase over normal operations and included a number of incidents that were directly related to work zone traffic control. Given the review of each UD-10 report form diagram and narrative, the most common circumstance directly related to work zone temporary traffic control was rear end collisions related to vehicles stopping or slowing.

Traffic Crashes by Ramp: I-94 (Britain Avenue to I-196 Interchange)

Ramp Information			Average AADT	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.		Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
EB Exit Ramp to I-196	0.354	EB	13,750	1,461	15	3	577	6	3	0.010	0.010
SB I-196 EB Entrance Ramp	0.518	EB	420	1,461	12	0	577	6	1	0.008	0.010
WB Exit Ramp to I-196	0.341	WB	314	1,461	0	0	577	1	0	0.000	0.002
I-196 WB Entrance Ramp	0.572	WB	14,398	1,461	8	0	577	7	2	0.005	0.012
All Ramps	**1.784**	**-**	**7,221**	**5,844**	**35**	**3**	**2,308**	**20**	**6**	**0.006**	**0.009**

Work Zone Traffic Crashes by Circumstance: I-94 (Britain Avenue to I-196 Interchange)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	7	3.5%
	Vehicle(s) Struck Channelizing Devices	4	2.0%
	Sideswipe Same Collisions Related to Lane Closure	4	2.0%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	27	13.6%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	2	1.0%
	Vehicle(s) Entered Work Area	0	0.0%
	Collisions involving Work Vehicles	2	1.0%
	Collisions involving Workers	0	0.0%
	Other Work Zone Related Motor Vehicle Crashes	2	1.0%
	All Motor Vehicle Crashes Directly Related to Work Zone	**48**	**24.1%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	59	29.6%
	Other Sideswipe Same Collisions	43	21.6%
	Other Rear End Collisions	17	8.5%
	Rear End Collisions at Ramp Termini	0	0.0%
	Vehicles Striking Loose Objects on Roadway	16	8.0%
	Vehicles Struck Pedestrian on Freeway	0	0.0%
	Vehicles Struck Pedestrian at Ramp Termini	0	0.0%
	Vehicles Struck Bicyclist at Ramp Termini	0	0.0%
	Other Motor Vehicle Crashes	16	8.0%
	All Other Motor Vehicle Crashes	**151**	**75.9%**
	Total	**199**	**100.0%**

A.18 Widening Project along I-75 (Hess Avenue to I-675 Interchange)

The suburban freeway project shown in the map below included an approximately 1.7-mile widening effort along I-75 as it runs east of Saginaw, Michigan. The project included the use of moveable barrier walls to accommodate a series of crossovers and was completed during the 2020 to 2022 construction seasons. It should also be noted that there were limitations in identifying the timing of specific stages and associated temporary traffic control configurations. This primarily impacted the ability to disaggregate the project beyond analyzing the major stages.

Map of I-75 (Hess Avenue to I-675 Interchange) Widening Project

Aside from an unrelated prior construction project in 2016, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2020. Therefore, data from 2017-2019 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: I-75 (Hess Avenue to I-675 Interchange)

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	29,914	30,598	174,642,543	144	22	42	29.2%	82.5	12.6	24.0
2017	29,914	30,598	174,165,377	95	21	1	1.1%	54.5	12.1	0.6
2018	29,901	29,418	170,807,156	129	25	1	0.8%	75.5	14.6	0.6
2019	29,990	29,150	170,255,010	124	16	1	0.8%	72.8	9.4	0.6
2020	25,970	25,364	148,009,402	103	15	13	12.6%	69.6	10.1	8.8
2021	30,091	26,891	164,044,773	168	37	56	33.3%	102.4	22.6	34.1
2022	29,513	28,295	166,681,827	129	26	13	10.1%	77.4	15.6	7.8
2023	30,496	29,306	172,395,322	87	18	0	0.0%	50.5	10.4	0.0
All Years	**29,474**	**28,703**	**1,341,001,408**	**979**	**180**	**127**	**13.0%**	**73.0**	**13.4**	**9.5**

The crash rate during the work period (85.9) was considerably higher compared to the rate observed for the corridor under normal operations (67.5 for the years 2017 to 2019). When compared to performance under normal operations observed during the construction season (56.2), considerable increases were observed in both rear end and sideswipe same crash rates.

Summary of Work Zone Crash and Volume Data: I-75 (Hess Avenue to I-675 Interchange)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Pre-Stage Work 2020	4/27/2020	12/5/2020	223	Intermittent Lane and Shoulder Closures	90,180,592	55	7	13	23.6%	61.0	7.8	14.4
Winter 2020	12/6/2020	3/16/2021	101	All Lanes Open	44,913,853	52	9	0	0.0%	115.8	20.0	0.0
Pre-Stage Work 2021	3/17/2021	3/31/2021	15	Intermittent Lane and Shoulder Closures	6,741,566	7	2	4	57.1%	103.8	29.7	59.3
All Stages 2021	4/1/2021	11/30/2021	244	Reconstruction Work	109,662,807	106	26	52	49.1%	96.7	23.7	47.4
Winter 2021	12/1/2021	3/31/2022	121	All Lanes Open	55,350,520	61	8	1	1.6%	110.2	14.5	1.8
All Stages 2022	4/1/2022	9/1/2022	154	Intermittent Lane and Shoulder Closures	70,326,031	43	7	12	27.9%	61.1	10.0	17.1
All Stages	**4/27/2020**	**9/1/2022**	**858**		**377,175,369**	**324**	**59**	**82**	**25.3%**	**85.9**	**15.6**	**21.7**

Crash Rates by Worst Injury/Type: I-75 (Hess Ave. to I-675 Interchange) – *Excludes Winter Shutdown*

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.0	0.4
Severe Injury (A)	0.8	1.4
Minor Injury (B)	2.6	3.3
Possible Injury (C)	4.9	10.1
Property Damge Only	47.9	61.0
Total	**56.2**	**76.2**

Crash Type	Normal Operations	All Stages
Single Vehicle	31.3	26.7
Head On	0.0	0.0
Angle	0.3	0.0
Rear End	9.6	25.3
Sideswipe Same	10.1	19.1
Sideswipe Opposite	0.0	0.0
Other	4.9	5.1
Total	**56.2**	**76.2**

Overall, approximately 73.3 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations. This represents an increase of approximately 29.2 percent. These increases were driven by severely degraded performance along northbound I-75.

Total Traffic Crashes by Stage: I-75 (Hess Avenue to I-675 Interchange)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Pre-Stage Work 2020	Intermittent Lane and Shoulder Closures	4/27/2020	12/5/2020	223	48.7	50.8	50.5	55.0	+4.5	8.9%
Winter 2020	All Lanes Open	12/6/2020	3/16/2021	101	40.0	44.5	42.9	52.0	+9.1	21.2%
Pre-Stage Work 2021	Intermittent Lane and Shoulder Closures	3/17/2021	3/31/2021	15	3.6	3.8	3.8	7.0	+3.2	86.5%
All Stages 2021	Reconstruction Work	4/1/2021	11/30/2021	244	58.8	61.5	61.0	106.0	+45.0	73.7%
Winter 2021	All Lanes Open	12/1/2021	3/31/2022	121	48.9	55.4	53.2	61.0	+7.8	14.6%
All Stages 2022	Intermittent Lane and Shoulder Closures	4/1/2022	9/1/2022	154	37.7	39.5	39.3	43.0	+3.7	9.6%
All Stages		4/27/2020	9/1/2022	858	237.7	255.5	250.7	324.0	+73.3	29.2%

Total Crashes by Area: I-75 (Hess Avenue to I-675 Interchange) – *Excludes Winter Shutdown*

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
I-75 NB	Upstream	28,512	31.5	30.8	31.0	32.0	+1.0	3.4%
	Activity	30,287	19.7	36.7	33.0	58.0	+25.0	75.6%
	Downstream	22,608	20.9	18.5	19.1	30.0	+10.9	57.0%
All Northbound Areas		**27,136**	**72.1**	**86.0**	**83.1**	**120.0**	**+36.9**	**44.4%**
I-75 SB	Upstream	25,400	23.1	18.9	19.9	30.0	+10.1	50.7%
	Activity	31,764	20.5	31.5	29.3	36.0	+6.7	23.0%
	Downstream	30,253	33.1	19.4	22.3	25.0	+2.7	12.2%
All Soundbound Areas		**29,139**	**76.7**	**69.7**	**71.4**	**91.0**	**+19.6**	**27.4%**

In general, there were not major changes in performance along the ramps impacted by the work. However, it should be noted that consistent details specific to the dates of ramp closures were unavailable and therefore the number of days is likely less than 858 for each ramp presented below. Given the review of each UD-10 report form diagram and narrative, the most common circumstance directly related to work zone temporary traffic control was rear end collisions related to vehicles stopping or slowing.

Traffic Crashes by Ramp: I-75 (Hess Avenue to I-675 Interchange)

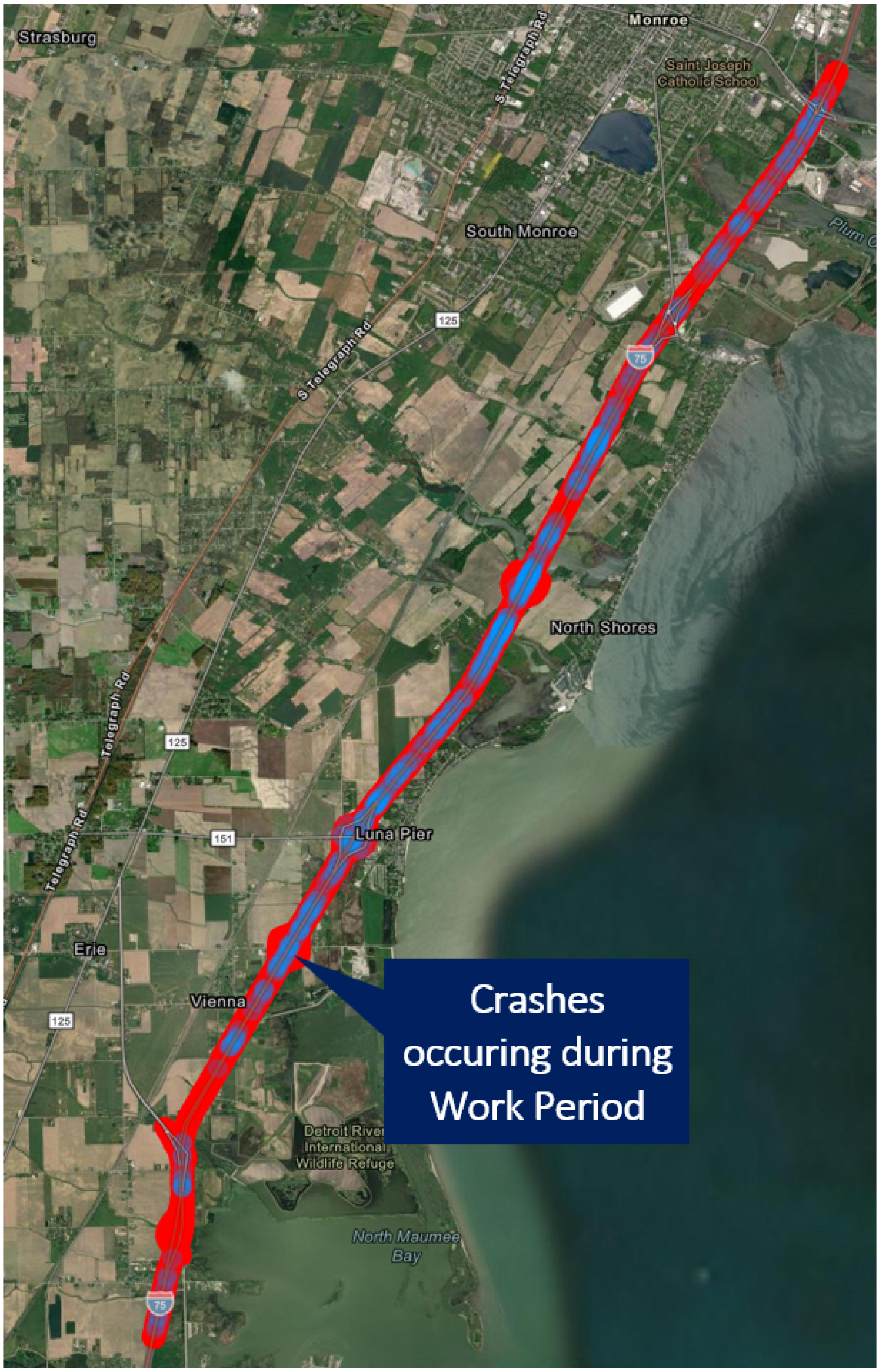
Ramp Information			Average	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.	AADT	Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
NB Exit Ramp to EB M-46	0.410	NB	1,514	1,095	3	0	858	0	0	0.003	0.000
EB M-46 Entrance Ramp to NB I-75	0.250	NB	1,885	1,095	2	0	858	0	0	0.002	0.000
NB Exit Ramp to WB M-46	0.250	NB	2,099	1,095	3	0	858	2	0	0.003	0.002
WB M-46 Entrance Ramp to NB I-75	0.374	NB	5,064	1,095	2	0	858	1	0	0.002	0.001
NB Exit Ramp to NB I-675	0.581	NB	10,498	1,095	21	0	858	9	1	0.019	0.010
SB I-675 Entrance Ramp to NB I-75	0.683	SB	1,259	1,095	7	0	858	5	1	0.006	0.006
SB Exit Ramp to NB I-675	0.410	SB	763	1,095	2	0	858	3	0	0.002	0.003
SB I-675 Entrance Ramp to SB I-75	0.595	SB	9,816	1,095	15	0	858	14	3	0.014	0.016
SB Exit Ramp to WB M-46	0.358	SB	3,298	1,095	2	0	858	2	0	0.002	0.002
WB M-46 Entrance Ramp to SB I-75	0.224	SB	1,673	1,095	1	0	858	2	1	0.001	0.002
SB Exit Ramp to EB M-46	0.250	SB	4,766	1,095	3	0	858	2	1	0.003	0.002
EB M-46 Entrance Ramp to SB I-75	0.400	SB	2,821	1,095	3	0	858	2	2	0.003	0.002
All Ramps	**4.784**	**-**	**3,788**	**13,140**	**64**	**0**	**10,296**	**42**	**9**	**0.005**	**0.004**

Work Zone Traffic Crashes by Circumstance: I-75 (Hess Avenue to I-675 Interchange)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	4	1.1%
	Vehicle(s) Struck Channelizing Devices	5	1.4%
	Sideswipe Same Collisions Related to Lane Closure	4	1.1%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	44	12.0%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	11	3.0%
	Vehicle(s) Entered Work Area	0	0.0%
	Collisions involving Work Vehicles	0	0.0%
	Collisions involving Workers	1	0.3%
	Other Work Zone Related Motor Vehicle Crashes	4	1.1%
	All Motor Vehicle Crashes Directly Related to Work Zone	**73**	**19.9%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	146	39.9%
	Other Sideswipe Same Collisions	70	19.1%
	Other Rear End Collisions	38	10.4%
	Rear End Collisions at Ramp Termini	1	0.3%
	Vehicles Striking Loose Objects on Roadway	14	3.8%
	Vehicles Struck Pedestrian on Freeway	0	0.0%
	Vehicles Struck Pedestrian at Ramp Termini	0	0.0%
	Vehicles Struck Bicyclist at Ramp Termini	0	0.0%
	Other Motor Vehicle Crashes	24	6.6%
	All Other Motor Vehicle Crashes	**293**	**80.1%**
	Total	**366**	**100.0%**

A.19 Reconstruction Project along I-75 (Erie Road to Otter Creek)

The rural freeway project shown in the map below included approximately 3.7 miles of reconstruction work along I-75 north of the Ohio-Michigan State line. The project was completed during the 2022- 2024 construction seasons primarily via crossovers. It should be noted that the 2024 work falls outside of the 2016 to 2023 study period and is not included in the analysis.



Map of I-75 (Erie Road to Otter Creek) Reconstruction Project

Aside from the COVID-19 pandemic and an unrelated project in 2019, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2022. Therefore, data from 2016 to 2018 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: I-75 (Erie Road to Otter Creek)

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	30,100	30,390	220,759,490	158	19	6	3.8%	71.6	8.6	2.7
2017	30,100	24,990	190,357,995	116	24	5	4.3%	60.9	12.6	2.6
2018	30,300	30,494	220,524,399	144	25	3	2.1%	65.3	11.3	1.4
2019	28,601	29,442	210,350,543	243	46	87	35.8%	115.5	21.9	41.4
2020	22,862	20,875	159,402,746	133	27	44	33.1%	83.4	16.9	27.6
2021	30,202	28,504	213,585,506	117	18	12	10.3%	54.8	8.4	5.6
2022	29,108	29,014	212,119,772	134	24	32	23.9%	63.2	11.3	15.1
2023	29,866	29,804	217,762,774	237	40	117	49.4%	108.8	18.4	53.7
All Years	**28,892**	**27,939**	**1,644,863,224**	**1,282**	**223**	**306**	**23.9%**	**77.9**	**13.6**	**18.6**

The crash rate during the work period (88.3) was considerably higher compared to the rate observed for the corridor under normal operations (66.2 for the years 2016 to 2018). When compared to performance under normal operations observed during the construction season (55.7), considerable increases were observed in both rear end and sideswipe same crash rates.

Summary of Work Zone Traffic Crash and Volume Data: I-75 (Erie Road to Otter Creek)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Stages 1&2	5/9/2022	9/28/2022	143	Single Lane Closures	83,168,648	56	8	30	53.6%	67.3	9.6	36.1
Winter 2022	9/29/2022	3/7/2023	160	All Lanes Open	95,425,585	51	13	2	3.9%	53.4	13.6	2.1
Stage 3	3/8/2023	12/6/2023	274	Crossover (NB in SB Roadbed)	163,352,990	201	31	114	56.7%	123.0	19.0	69.8
Winter 2023	12/7/2023	12/31/2023	25	All Lanes Open	14,910,248	7	2	3	42.9%	46.9	13.4	20.1
All Stages	**5/9/2022**	**12/31/2023**	**602**		**356,857,471**	**315**	**54**	**149**	**47.3%**	**88.3**	**15.1**	**41.8**

Crash Rates by Worst Injury/Type: I-75 (Erie Road to Otter Creek) – *Excludes Winter Shutdown*

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.2	0.0
Severe Injury (A)	1.3	2.8
Minor Injury (B)	3.0	6.5
Possible Injury (C)	5.1	6.5
Property Damge Only	46.2	88.4
Total	**55.7**	**104.3**

Crash Type	Normal Operations	All Stages
Single Vehicle	25.1	25.1
Head On	0.0	0.0
Angle	0.0	0.0
Rear End	9.5	33.3
Sideswipe Same	14.8	36.9
Sideswipe Opposite	0.0	0.4
Other	6.3	8.5
Total	**55.7**	**104.3**

Overall, approximately 78.9 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations. This represents an increase of approximately 33.4 percent. These increases were driven by severely degraded performance along both directions of I-75.

Total Traffic Crashes by Stage: I-75 (Erie Road to Otter Creek)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Stages 1&2	Single Lane Closures	5/9/2022	9/28/2022	143	44.6	45.4	45.2	56.0	+10.8	23.8%
Winter 2022	All Lanes Open	9/29/2022	3/7/2023	160	83.7	91.0	88.6	51.0	-37.6	-42.5%
Stage 3	Crossover (NB in SB Roadbed)	3/8/2023	12/6/2023	274	87.5	88.8	88.4	201.0	+112.6	127.3%
Winter 2023	All Lanes Open	12/7/2023	12/31/2023	25	13.1	14.2	13.8	7.0	-6.8	-49.5%
All Stages		5/9/2022	12/31/2023	602	228.8	239.4	236.1	315.0	+78.9	33.4%

Total Traffic Crashes by Area: I-75 (Erie Road to Otter Creek) – *Excludes Winter Shutdown*

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
I-75 NB	Upstream	28,631	6.4	5.9	6.0	8.0	+2.0	33.6%
	Advance Warning	28,630	15.8	16.7	16.5	15.0	-1.5	-8.9%
	Transition	28,859	2.4	2.3	2.3	12.0	+9.7	422.4%
	Activity	29,696	29.9	23.9	25.2	66.0	+40.8	162.3%
	Termination	31,148	1.0	0.7	0.7	3.0	+2.3	306.7%
	Downstream	30,690	6.9	3.0	3.8	10.0	+6.2	161.5%
All Northbound Areas		29,609	62.4	52.4	54.5	114.0	+59.5	109.2%
I-75 SB	Upstream	30,582	6.8	12.3	11.2	17.0	+5.8	51.9%
	Advance Warning	30,134	19.6	16.6	17.2	40.0	+22.8	132.1%
	Transition	29,686	1.9	2.0	2.0	5.0	+3.0	151.6%
	Activity	28,978	33.8	34.9	34.7	77.0	+42.3	122.2%
	Termination	27,880	0.8	1.2	1.1	0.0	-1.1	-100.0%
	Downstream	28,071	6.7	14.8	13.0	4.0	-9.0	-69.2%
All Soundbound Areas		29,222	69.7	81.8	79.2	143.0	+63.8	80.6%

In general, there were not major changes in performance along the ramps impacted by the work. Given the review of each UD-10 report form diagram and narrative, the most common circumstance directly related to work zone temporary traffic control was rear end collisions related to vehicles stopping or slowing.

Traffic Crashes by Ramp: I-75 (Erie Road to Otter Creek)

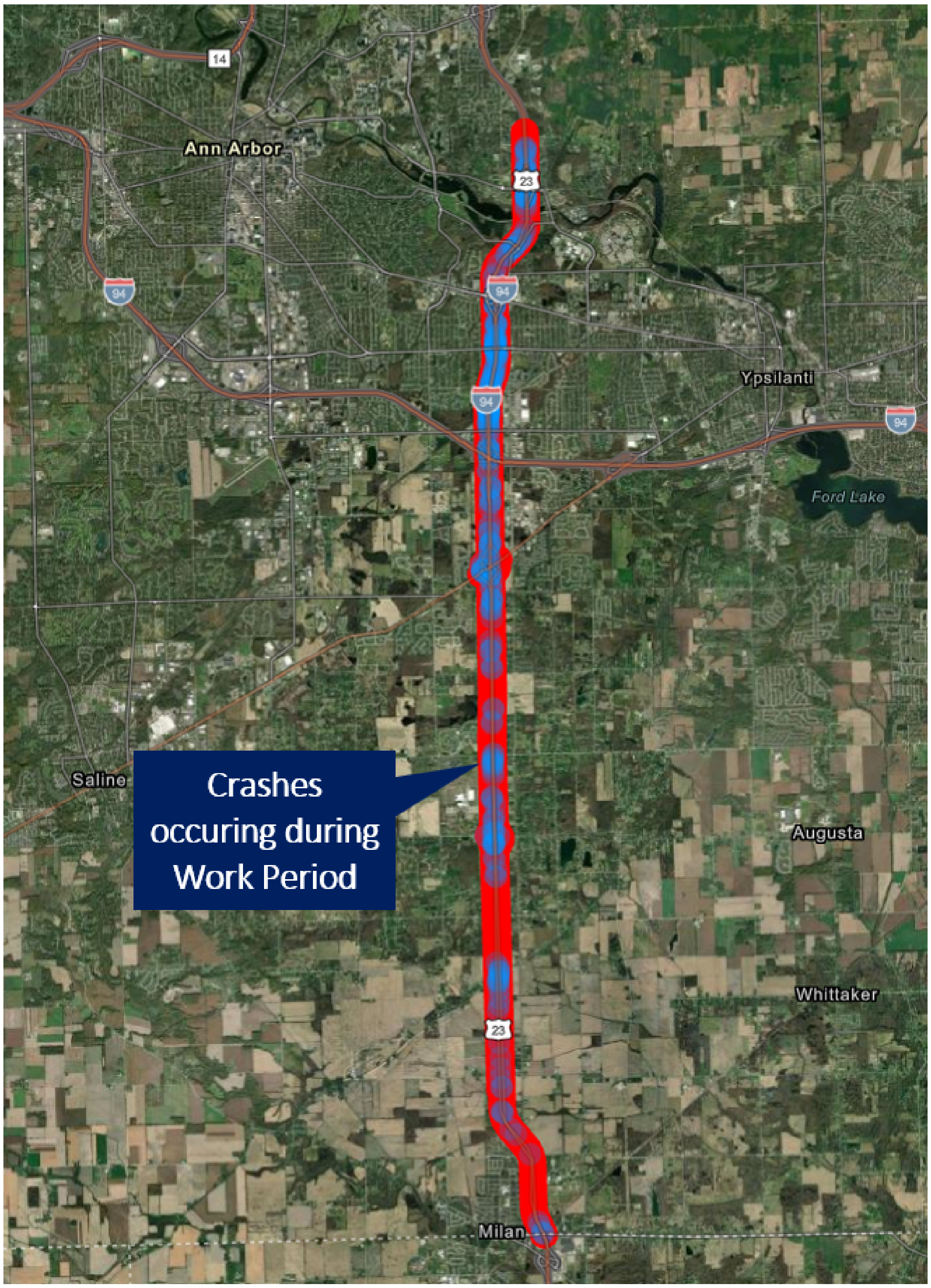
Ramp Information			Average AADT	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.		Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
NB Erie Rd Exit Ramp	0.443	NB	135	1,096	1	0	602	0	0	0.001	0.000
Erie Rd NB Entrance Ramp	0.172	NB	454	1,096	0	0	602	1	0	0.000	0.002
NB Luna Pier Rd Exit Ramp	0.388	NB	965	1,096	2	0	556	3	2	0.002	0.005
Luna Pier Rd NB Entrance Ramp	0.310	NB	1,914	1,096	1	0	570	0	0	0.001	0.000
NB Otter Creek Rd Exit Ramp	0.274	NB	379	1,096	3	0	531	0	0	0.003	0.000
Otter Creek Rd NB Entrance Ramp	0.274	NB	864	1,096	1	0	602	0	0	0.001	0.000
SB Luna Pier Rd Exit Ramp	0.418	SB	2,027	1,096	4	0	602	3	1	0.004	0.005
Luna Pier Rd SB Entrance Ramp	0.256	SB	957	1,096	1	0	602	0	0	0.001	0.000
SB Erie Rd Exit Ramp	0.396	SB	451	1,096	6	0	602	0	0	0.005	0.000
Erie Rd SB Entrance Ramp	0.274	SB	123	1,096	0	0	602	0	0	0.000	0.000
SB Otter Creek Rd Exit Ramp	0.274	SB	866	1,096	4	0	602	1	0	0.004	0.002
Otter Creek Rd SB Entrance Ramp	0.274	SB	396	1,096	1	0	602	0	0	0.001	0.000
All Ramps	3.754	-	794	13,152	24	0	7,075	8	3	0.002	0.001

Work Zone Traffic Crashes by Circumstance: I-75 (Erie Road to Otter Creek)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	5	1.5%
	Vehicle(s) Struck Channelizing Devices	1	0.3%
	Sideswipe Same Collisions Related to Lane Closure	1	0.3%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	65	20.1%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	5	1.5%
	Vehicle(s) Entered Work Area	0	0.0%
	Collisions involving Work Vehicles	2	0.6%
	Collisions involving Workers	0	0.0%
	Other Work Zone Related Motor Vehicle Crashes	11	3.4%
	All Motor Vehicle Crashes Directly Related to Work Zone	**90**	**27.9%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	51	15.8%
	Other Sideswipe Same Collisions	97	30.0%
	Other Rear End Collisions	28	8.7%
	Rear End Collisions at Ramp Termini	1	0.3%
	Vehicles Striking Loose Objects on Roadway	21	6.5%
	Vehicles Struck Pedestrian on Freeway	1	0.3%
	Vehicles Struck Pedestrian at Ramp Termini	0	0.0%
	Vehicles Struck Bicyclist at Ramp Termini	0	0.0%
	Other Motor Vehicle Crashes	34	10.5%
	All Other Motor Vehicle Crashes	**233**	**72.1%**
	Total	**323**	**100.0%**

A.20 Resurfacing/Reconstruction Project along US-23 (Stoney Creek Rd. to Ellsworth Rd.)

The suburban freeway project shown in the map below included approximately 7.3 miles of resurfacing and reconstruction work along US-23 south of Ann Arbor and Ypsilanti. This work was primarily completed during the 2023 construction season, with final closeout of the project occurring in 2024 (which is not included in the evaluation). The project began with off-peak inside lane closures to build crossovers and temporary pavement to support four split merge stages.



Map of US-23 (Stoney Creek Road to Ellsworth Road) Project

Aside from the COVID-19 pandemic, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2023. Therefore, data from 2016-2019 and 2021-2022 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: US-23 (Stoney Creek Rd. to Ellsworth Rd.)

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	34,843	37,631	292,779,552	198	34	0	0.0%	67.6	11.6	0.0
2017	34,843	37,631	291,979,607	236	46	0	0.0%	80.8	15.8	0.0
2018	38,292	39,547	306,272,257	219	42	1	0.5%	71.5	13.7	0.3
2019	34,636	34,671	286,196,502	201	34	3	1.5%	70.2	11.9	1.0
2020	28,967	28,808	238,165,388	127	28	0	0.0%	53.3	11.8	0.0
2021	31,140	32,657	265,990,926	162	31	1	0.6%	60.9	11.7	0.4
2022	33,700	32,880	269,619,692	171	33	0	0.0%	63.4	12.2	0.0
2023	34,388	33,457	275,633,706	284	49	108	38.0%	103.0	17.8	39.2
All Years	**33,851**	**34,660**	**2,226,637,629**	**1,598**	**297**	**113**	**7.1%**	**71.8**	**13.3**	**5.1**

While traffic crash rates tended to be highest during the stages that included the split merge configurations, the crash rate was considerably higher during the work period for both total (108.1) and FI (18.2) crashes compared to the rate observed for the corridor under normal operations. This was primarily driven by an increase in the rate of rear end and sideswipe same crashes compared to performance under normal operations observed during the construction season.

Summary of Work Zone Crash/Volume Data: US-23 (Stoney Creek Rd. to Ellsworth Rd.)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Stage 1	3/1/2023	6/18/2023	110	Offpeak Lane Closures	83,066,837	78	14	24	30.8%	93.9	16.9	28.9
Stage 2b	6/19/2023	7/24/2023	36	Split Merge	27,147,895	39	6	15	38.5%	143.7	22.1	55.3
Stage 2a	7/25/2023	9/9/2023	47	Split Merge	35,322,179	49	12	26	53.1%	138.7	34.0	73.6
Stage 3a	9/10/2023	11/10/2023	62	Split Merge	46,460,087	58	7	28	48.3%	124.8	15.1	60.3
Stage 3b	11/11/2023	12/22/2023	42	Split Merge	31,604,555	25	3	15	60.0%	79.1	9.5	47.5
Winter 2023	12/23/2023	12/31/2023	9	All Lanes Open	6,796,378	0	0	0		0.0	0.0	0.0
All Stages	**3/1/2023**	**12/31/2023**	**306**		**230,397,932**	**249**	**42**	**108**	**43.4%**	**108.1**	**18.2**	**46.9**

Crash Rates by Worst Injury/Type: US-23 (Stoney Creek Rd. to Ellsworth Rd.) – *Excludes Winter Shutdown*

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.1	0.0
Severe Injury (A)	1.0	2.2
Minor Injury (B)	3.0	4.5
Possible Injury (C)	7.9	12.1
Property Damge Only	52.3	92.6
Total	**64.2**	**111.4**

Crash Type	Normal Operations	All Stages
Single Vehicle	18.6	30.4
Head On	0.2	0.0
Angle	0.4	0.0
Rear End	28.0	55.5
Sideswipe Same	13.0	24.6
Sideswipe Opposite	0.3	0.0
Other	3.7	0.9
Total	**64.2**	**111.4**

Overall, approximately 101.3 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations. This represents an increase of approximately 68.6 percent. The largest safety performance impacts were observed along southbound US-23 and where the split merge was in place.

Total Traffic Crashes by Stage: US-23 (Stoney Creek Rd. to Ellsworth Rd.)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Stage 1	Offpeak Lane Closures	3/1/2023	6/18/2023	110	44.3	53.3	52.6	78.0	+25.4	48.2%
Stage 2b	Split Merge	6/19/2023	7/24/2023	36	14.5	17.4	17.2	39.0	+21.8	126.5%
Stage 2a	Split Merge	7/25/2023	9/9/2023	47	18.8	22.7	22.5	49.0	+26.5	118.3%
Stage 3a	Split Merge	9/10/2023	11/10/2023	62	24.8	29.9	29.5	58.0	+28.5	96.3%
Stage 3b	Split Merge	11/11/2023	12/22/2023	42	16.9	20.3	20.1	25.0	+4.9	24.6%
Winter 2023	All Lanes Open	12/23/2023	12/31/2023	9	5.8	5.8	5.8	0.0	-5.8	-100.0%
All Stages		3/1/2023	12/31/2023	306	125.1	149.4	147.7	249.0	+101.3	68.6%

Total Crashes by Area: US-23 (Stoney Creek Rd. to Ellsworth Rd.) – *Split Merges Only*

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
US-23 NB	Upstream	28,894	1.7	0.7	0.8	5.0	+4.2	496.7%
	Advance Warning	28,904	10.9	13.2	12.9	10.0	-2.9	-22.4%
	Transition	28,894	1.7	0.6	0.7	4.0	+3.3	474.1%
	Activity	31,178	33.7	28.0	28.8	53.0	+24.2	84.0%
	Termination	40,043	2.9	8.3	7.8	11.0	+3.2	40.9%
	Downstream	40,043	6.3	5.8	5.9	13.0	+7.1	121.0%
All Northbound Areas		32,993	57.2	56.5	56.9	96.0	+39.1	68.7%
US-23 SB	Upstream	37,751	5.9	26.7	24.6	30.0	+5.4	21.7%
	Advance Warning	39,002	14.5	25.0	24.0	61.0	+37.0	154.0%
	Transition	40,253	2.5	3.3	3.2	6.0	+2.8	88.0%
	Activity	30,820	33.9	29.6	30.3	51.0	+20.7	68.5%
	Termination	26,980	0.9	0.6	0.6	3.0	+2.4	372.9%
	Downstream	26,980	4.3	1.9	2.2	2.0	-0.2	-11.0%
All Soundbound Areas		33,631	62.0	87.1	85.0	153.0	+68.0	80.0%

Total Traffic Crashes by Type of Activity: US-23 (Stoney Creek Rd. to Ellsworth Rd.)

Type of Activity	VMT	Crashes during Normal Operations			Crashes during Work Zone Operations		
		Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Offpeak Inside Lane Closures	52,597,917	28.1	26.1	26.5	40.0	+13.5	50.8%
Crossover (Normal)	36,863,960	19.7	15.9	16.4	28.0	+11.6	70.5%
Split Merge (1 Opp+1 Inside)	21,425,921	11.5	9.1	9.4	22.0	+12.6	134.5%
Split Merge (1 Opp+1 Outside)	15,343,020	8.2	6.5	6.7	14.0	+7.3	107.5%

In general, there were not major changes in safety performance along the ramps impacted by the work activity. A total of 17 collisions occurred along these ramp facilities during the study period, where two strikes of channelizing devices and other temporary traffic control devices represented the only collisions directly related to the work zone.

Traffic Crashes by Ramp: US-23 (Stoney Creek Rd. to Ellsworth Rd.)

Ramp Information			Average	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.	AADT	Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
NB Exit Ramp to Willis Rd	0.369	NB	1,326	2,191	3	0	303	0	0	0.001	0.000
EB Willis Rd NB Entrance Ramp	0.262	NB	3,096	2,191	1	0	186	1	0	0.000	0.005
WB Willis Rd NB Entrance Ramp	0.314	NB	1,937	2,191	2	0	301	0	0	0.001	0.000
NB Exit Ramp to US-12	0.368	NB	2,093	2,191	9	0	252	0	0	0.004	0.000
US-12 NB Entrance Ramp	0.285	NB	8,271	2,191	6	0	275	1	1	0.003	0.004
NB Exit Ramp to I-94	0.149	NB	15,633	2,191	4	0	306	3	0	0.002	0.010
I-94 NB Entrance Ramp	0.219	NB	21,260	2,191	12	0	306	2	1	0.005	0.007
SB Exit Ramp to I-94	0.216	SB	8,188	2,191	7	0	306	0	0	0.003	0.000
I-94 SB Entrance Ramp	0.116	SB	15,046	2,191	6	0	306	0	0	0.003	0.000
SB Exit Ramp to US-12	0.370	SB	8,286	2,191	70	0	275	8	4	0.032	0.029
US-12 SB Entrance Ramp	0.284	SB	2,070	2,191	1	0	259	0	0	0.000	0.000
SB Exit Ramp to Willis Rd	0.300	SB	4,496	2,191	63	0	303	1	0	0.029	0.003
Willis Rd SB Entrance Ramp	0.303	SB	1,397	2,191	1	0	303	1	1	0.000	0.003
All Ramps	**3.556**	**-**	**7,162**	**28,483**	**185**	**0**	**3,681**	**17**	**7**	**0.006**	**0.005**

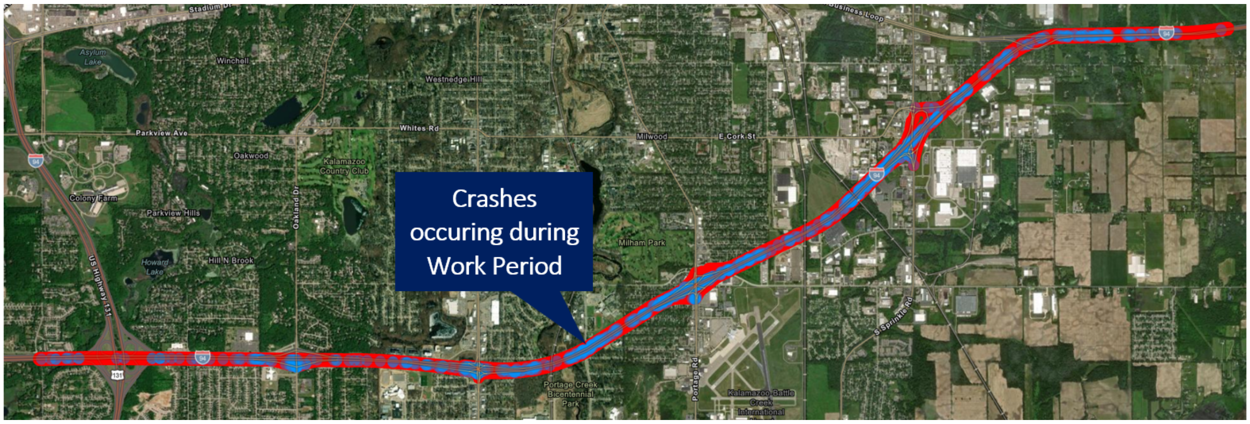
Given the review of each UD-10 crash report form diagram and narrative, the most common circumstance directly related to work zone temporary traffic control was rear end collisions related to vehicles stopping or slowing. Ten strikes of channelizing devices or other temporary traffic control were noted by responding officers.

Work Zone Traffic Crashes by Circumstance: US-23 (Stoney Creek Rd. to Ellsworth Rd.)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	4	1.5%
	Vehicle(s) Struck Channelizing Devices	6	2.3%
	Sideswipe Same Collisions Related to Lane Closure	3	1.1%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	38	14.3%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	3	1.1%
	Vehicle(s) Entered Work Area	0	0.0%
	Collisions involving Work Vehicles	3	1.1%
	Collisions involving Workers	0	0.0%
	Other Work Zone Related Motor Vehicle Crashes	14	5.3%
	All Motor Vehicle Crashes Directly Related to Work Zone	**71**	**26.7%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	42	15.8%
	Other Sideswipe Same Collisions	44	16.5%
	Other Rear End Collisions	84	31.6%
	Rear End Collisions at Ramp Termini	8	3.0%
	Vehicles Striking Loose Objects on Roadway	8	3.0%
	Vehicles Struck Pedestrian on Freeway	0	0.0%
	Vehicles Struck Pedestrian at Ramp Termini	0	0.0%
	Vehicles Struck Bicyclist at Ramp Termini	0	0.0%
	Other Motor Vehicle Crashes	9	3.4%
	All Other Motor Vehicle Crashes	**195**	**73.3%**
	Total	**266**	**100.0%**

A.21 Reconstruction Project along I-94 (Lovers Lane to Sprinkle Road)

The urban freeway project shown in the map below included an approximately 2.7-mile widening project along I-94 as it runs south of Kalamazoo, Michigan. It should be noted the project also included converting Portage Road to a single point urban interchange. The work was completed via a series of crossovers during the 2021 to 2023 construction seasons.



Map of I-94 (Lovers Lane to Sprinkle Road) Reconstruction Project

Aside from the COVID-19 pandemic, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2021. Therefore, data from 2016-2019 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: I-94 (Lovers Lane to Sprinkle Road)

Year	Average EB AADT	Average WB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	33,665	33,665	171,277,752	173	35	2	1.2%	101.0	20.4	1.2
2017	39,637	37,456	197,377,984	203	35	5	2.5%	102.8	17.7	2.5
2018	40,343	37,765	200,153,860	171	39	0	0.0%	85.4	19.5	0.0
2019	39,131	36,591	193,281,859	215	42	7	3.3%	111.2	21.7	3.6
2020	30,349	29,340	152,038,446	109	20	13	11.9%	71.7	13.2	8.6
2021	32,950	32,271	164,926,495	184	36	46	25.0%	111.6	21.8	27.9
2022	33,666	31,859	165,679,687	218	36	97	44.5%	131.6	21.7	58.5
2023	34,445	34,251	175,510,312	167	24	36	21.6%	95.2	13.7	20.5
All Years	35,523	34,150	1,420,246,395	1,440	267	206	14.3%	101.4	18.8	14.5

Traffic crash rates during the work period across the entire corridor (99.7) were similar to what is typically observed during a typical year with no construction activity (100.0 for the years 2016 to 2019). The crash rate observed during a typical construction-season along this corridor is slightly lower (100.0), where the corridor experienced larger rates of sideswipe same collisions during work activity with lower rates of rear end collisions.

Summary of Work Zone Crash and Volume Data: I-94 (Lovers Lane to Sprinkle Road)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Pre-Stage	4/13/2021	4/24/2021	12	Pre-Stage Work	6,285,447	3	1	0	0.0%	47.7	15.9	0.0
Stage 1b	4/25/2021	7/5/2021	72	Crossover (EB in WB Roadbed)	37,358,929	33	8	12	36.4%	88.3	21.4	32.1
Stage 1a	7/6/2021	4/20/2022	289	Crossover (EB in WB Roadbed)	146,677,101	156	26	64	41.0%	106.4	17.7	43.6
Stage 1c	4/21/2022	8/19/2022	121	Lane Closures/Lane Shifts	65,860,382	74	14	41	55.4%	112.4	21.3	62.3
Stage 2	8/20/2022	6/14/2023	299	Crossover (WB in EB Roadbed)	149,538,867	154	23	48	31.2%	103.0	15.4	32.1
Stage 3-1	6/15/2023	8/29/2023	76	Lane Closures/Lane Shifts	42,330,178	36	3	10	27.8%	85.0	7.1	23.6
Stage 3-2	8/30/2023	10/28/2023	60	Lane Closures/Lane Shifts	33,172,546	24	3	4	16.7%	72.3	9.0	12.1
All Stages	4/13/2021	10/28/2023	929		481,223,449	480	78	179	37.3%	99.7	16.2	37.2

Traffic Crash Rates by Worst Injury and Type: I-94 (Lovers Lane to Sprinkle Road)

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.5	0.4
Severe Injury (A)	1.7	2.1
Minor Injury (B)	5.0	3.3
Possible Injury (C)	12.6	10.4
Property Damge Only	80.2	83.5
Total	**100.0**	**99.7**

Crash Type	Normal Operations	All Stages
Single Vehicle	42.0	30.5
Head On	0.0	0.0
Angle	0.9	0.0
Rear End	27.9	36.4
Sideswipe Same	21.1	28.1
Sideswipe Opposite	0.0	0.0
Other	8.0	4.8
Total	**100.0**	**99.7**

Overall, approximately 60.0 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations. This represents an increase of approximately 14.3 percent. These increases were driven by degraded performance within the activity area along westbound I-94.

Total Traffic Crashes by Stage: I-94 (Lovers Lane to Sprinkle Road)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Pre-Stage	Pre-Stage Work	4/13/2021	4/24/2021	12	3.7	5.5	5.2	3.0	-2.2	-42.7%
Stage 1b	Crossover (EB in WB Roadbed)	4/25/2021	7/5/2021	72	21.9	32.7	31.1	33.0	+1.9	6.1%
Stage 1a	Crossover (EB in WB Roadbed)	7/6/2021	4/20/2022	289	84.3	128.0	121.3	156.0	+34.7	28.6%
Stage 1c	Lane Closures/Lane Shifts	4/21/2022	8/19/2022	121	40.2	57.6	55.2	74.0	+18.8	34.1%
Stage 2	Crossover (WB in EB Roadbed)	8/20/2022	6/14/2023	299	112.6	146.9	143.6	154.0	+10.4	7.2%
Stage 3-1	Lane Closures/Lane Shifts	6/15/2023	8/29/2023	76	26.3	37.0	35.6	36.0	+0.4	1.2%
Stage 3-2	Lane Closures/Lane Shifts	8/30/2023	10/28/2023	60	20.5	29.2	28.0	24.0	-4.0	-14.3%
All Stages		4/13/2021	10/28/2023	929	309.5	436.9	420.0	480.0	+60.0	14.3%

Total Traffic Crashes by Area: I-94 (Lovers Lane to Sprinkle Road)

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
I-94 EB	Upstream	29,299	11.0	16.7	15.7	11.0	-4.7	-29.8%
	Advance Warning	42,942	62.1	63.7	63.6	68.0	+4.4	6.9%
	Transition	42,316	6.8	8.0	7.9	14.0	+6.1	77.2%
	Activity	41,362	84.4	138.0	131.8	141.0	+9.2	7.0%
	Termination	37,028	14.0	27.1	25.2	13.0	-12.2	-48.4%
	Downstream	32,408	17.0	19.6	19.1	24.0	+4.9	25.6%
All Eastbound Areas		**37,559**	**195.3**	**273.1**	**263.3**	**271.0**	**+7.7**	**2.9%**
I-94 WB	Upstream	28,088	15.4	15.5	15.5	24.0	+8.5	54.6%
	Advance Warning	27,424	9.7	17.4	15.8	16.0	+0.2	1.5%
	Transition	28,944	2.4	5.6	5.1	4.0	-1.1	-21.6%
	Activity	35,169	56.7	84.2	80.4	120.0	+39.6	49.3%
	Termination	42,453	4.8	2.6	2.8	3.0	+0.2	7.3%
	Downstream	42,477	25.2	38.5	37.2	42.0	+4.8	13.0%
All Westbound Areas		**34,093**	**114.2**	**163.8**	**156.7**	**209.0**	**+52.3**	**33.3%**

In general, there were not major changes in performance along the ramps impacted by the work. Given the review of each UD-10 report form diagram and narrative, the most common circumstance directly related to work zone temporary traffic control was rear end collisions related to vehicles stopping or slowing.

Traffic Crashes by Ramp: I-94 (Lovers Lane to Sprinkle Road)

Ramp Information			Average	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.	AADT	Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
EB Exit Ramp to Oakland Dr	0.273	EB	6,724	1,461	25	0	929	14	0	0.017	0.015
Oakland Dr EB Entrance Ramp	0.232	EB	4,666	1,461	6	0	929	3	1	0.004	0.003
EB Exit Ramp to Westnedge Ave	0.392	EB	6,865	1,461	34	0	929	16	0	0.023	0.017
Westnedge Ave EB Entrance Ramp	0.367	EB	6,051	1,461	5	0	929	4	0	0.003	0.004
EB Exit Ramp to Portage Rd	0.294	EB	7,728	1,461	33	0	878	11	6	0.023	0.013
SB Portage EB Entrance Ramp	0.160	EB	593	1,461	2	0	6	0	0	0.001	0.000
NB Portage EB Entrance Ramp	0.253	EB	2,060	1,461	8	0	869	1	1	0.005	0.001
EB Exit Ramp to Sprinke Rd	0.340	EB	8,488	1,461	20	0	890	11	3	0.014	0.012
Sprinke Rd EB Entrance Ramp	0.387	EB	1,848	1,461	11	1	929	4	1	0.008	0.004
WB Exit Ramp to Sprinkle Road	0.313	WB	3,226	1,461	6	0	929	6	1	0.004	0.006
NB Sprinke to WB Entrance Ramp	0.294	WB	3,836	1,461	3	0	627	0	0	0.002	0.000
SB Sprinkle to WB Entrance Ramp	0.301	WB	7,635	1,461	7	0	832	1	0	0.005	0.001
WB Exit Ramp to Portage Road	0.254	WB	2,778	1,461	5	0	349	1	0	0.003	0.003
NB Portage WB Entrance Ramp	0.093	WB	2,556	1,461	0	0	6	0	0	0.000	0.000
SB Portage WB Entrance Ramp	0.193	WB	4,358	1,461	4	0	861	5	2	0.003	0.006
All Ramps	**4.147**	**-**	**4,627**	**21,915**	**169**	**1**	**10,892**	**77**	**15**	**0.008**	**0.007**

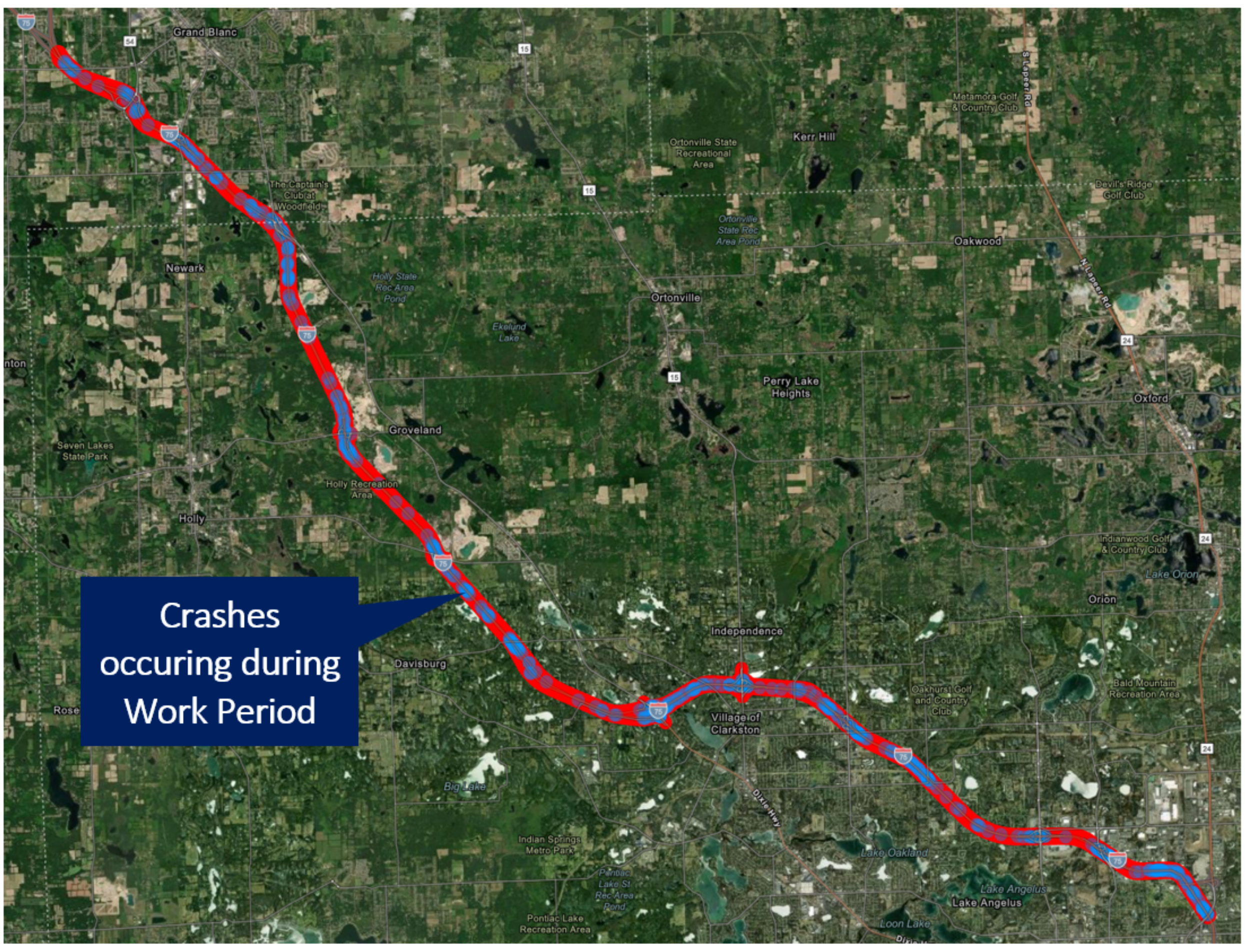
Work Zone Traffic Crashes by Circumstance: I-94 (Lovers Lane to Sprinkle Road)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	6	1.1%
	Vehicle(s) Struck Channelizing Devices	9	1.6%
	Sideswipe Same Collisions Related to Lane Closure	6	1.1%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	108	19.4%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	6	1.1%
	Vehicle(s) Entered Work Area	0	0.0%
	Collisions involving Work Vehicles	3	0.5%
	Collisions involving Workers	0	0.0%
	Other Work Zone Related Motor Vehicle Crashes	29	5.2%
	All Motor Vehicle Crashes Directly Related to Work Zone	**167**	**30.0%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	103	18.5%
	Other Sideswipe Same Collisions	126	22.6%
	Other Rear End Collisions	77	13.8%
	Rear End Collisions at Ramp Termini	26	4.7%
	Vehicles Striking Loose Objects on Roadway	23	4.1%
	Vehicles Struck Pedestrian on Freeway	1	0.2%
	Vehicles Struck Pedestrian at Ramp Termini	0	0.0%
	Vehicles Struck Bicyclist at Ramp Termini	3	0.5%
	Other Motor Vehicle Crashes	31	5.6%
	All Other Motor Vehicle Crashes	**390**	**70.0%**
	Total	**557**	**100.0%**

A.22 Pavement Rehabilitation Project along I-75 (M-15 to Oakland County Line)

The urban freeway project shown in the map below included approximately 15.0 miles of pavement rehabilitation along I-75 in Oakland County. While the project included a series of crossovers and split merge stages to complete the work, these stages occurred after the 2016 to 2023 study period. Only the single and double lane closures that were employed during the 2023 construction season are evaluated as a part of this study.

It should also be noted that there were limitations in identifying the timing of specific stages and associated temporary traffic control configurations. This primarily impacted the ability to disaggregate the project beyond analyzing the 2023 construction season as a single phase as well as the location of transition and termination areas. A dynamic stopped traffic advisory system was also employed as a part of the project.



Map of I-75 (M-15 to Oakland County Line) Pavement Rehabilitation Project

Aside from the COVID-19 pandemic and an unrelated project in 2019, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2023. Therefore, data from 2016-2018 and 2021-2022 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: I-75 (M-15 to Oakland County Line)

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	36,836	35,266	748,849,377	643	96	30	4.7%	85.9	12.8	4.0
2017	36,836	35,266	746,803,340	594	97	10	1.7%	79.5	13.0	1.3
2018	35,473	35,956	742,865,662	611	125	3	0.5%	82.2	16.8	0.4
2019	38,118	37,225	792,675,629	575	96	78	13.6%	72.5	12.1	9.8
2020	31,740	30,732	661,687,877	384	79	9	2.3%	58.0	11.9	1.4
2021	33,146	32,827	702,046,895	505	114	5	1.0%	71.9	16.2	0.7
2022	35,797	36,255	752,050,452	533	98	11	2.1%	70.9	13.0	1.5
2023	36,606	37,898	769,300,250	660	142	102	15.5%	85.8	18.5	13.3
All Years	**35,569**	**35,178**	**5,916,279,480**	**4,505**	**847**	**248**	**5.5%**	**76.1**	**14.3**	**4.2**

Traffic crash rates during the work period across the entire corridor (85.1) were slightly larger than what is typically observed during a typical year with no construction activity (78.2 for the years 2016 to 2018 and 2021 to 2022). The crash rate observed during a typical construction-season under normal operations along this corridor was slightly lower (69.2), where the corridor experienced a higher rate of rear end and sideswipe same collisions during the work period.

Summary of Work Zone Crash and Volume Data: I-75 (M-15 to Oakland County Line)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Stage 1	5/22/2023	12/14/2023	207	Single and Double Lane Closures	436,288,087	382	84	99	25.9%	87.6	19.3	22.7
Winter 23 24	12/15/2023	12/31/2023	17	All Lanes Open	35,830,423	20	4	0	0.0%	55.8	11.2	0.0
All Stages	**5/22/2023**	**12/31/2023**	**224**		**472,118,509**	**402**	**88**	**99**	**24.6%**	**85.1**	**18.6**	**21.0**

Crash Rates by Worst Injury/Type: I-75 (M-15 to Oakland County Line) – *Excludes Winter Shutdown*

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.2	0.7
Severe Injury (A)	1.5	0.5
Minor Injury (B)	4.5	4.6
Possible Injury (C)	7.1	13.5
Property Damge Only	55.9	68.3
Total	**69.2**	**87.6**

Crash Type	Normal Operations	All Stages
Single Vehicle	28.5	23.4
Head On	0.1	0.0
Angle	0.4	0.0
Rear End	19.2	34.8
Sideswipe Same	16.8	25.4
Sideswipe Opposite	0.1	0.0
Other	4.1	3.9
Total	**69.2**	**87.6**

Overall, approximately 59.6 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations. This represents an increase of approximately 17.4 percent.

Total Traffic Crashes by Stage: I-75 (M-15 to Oakland County Line)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Stage 1	Single and Double Lane Closures	5/22/2023	12/14/2023	207	255.9	310.8	305.2	382.0	+76.8	25.2%
Winter 23 24	All Lanes Open	12/15/2023	12/31/2023	17	33.9	37.9	37.3	20.0	-17.3	-46.3%
All Stages		5/22/2023	12/31/2023	224	289.9	348.8	342.4	402.0	+59.6	17.4%

Total Crashes by Area: I-75 (M-15 to Oakland County Line) – *Excludes Winter Shutdown*

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
I-75 NB	Advance Warning	50,973	73.5	107.0	105.1	95.0	-10.1	-9.6%
	Activity	29,740	48.3	53.4	51.9	87.0	+35.1	67.7%
	Downstream	28,061	10.7	17.7	16.4	21.0	+4.6	27.9%
All Northbound Areas		36,258	132.4	178.1	173.4	203.0	+29.6	17.1%
I-75 SB	Advance Warning	28,574	10.7	11.0	10.9	17.0	+6.1	55.4%
	Activity	30,024	50.0	52.4	52.0	98.0	+46.0	88.4%
	Downstream	47,243	62.9	69.4	68.8	64.0	-4.8	-7.0%
All Soundbound Areas		35,280	123.6	132.8	131.8	179.0	+47.2	35.8%

In general, there were not major changes in performance along the ramps impacted by the work. Given the review of each UD-10 report form diagram and narrative, the most common circumstance directly related to work zone temporary traffic control was rear end collisions related to vehicles stopping or slowing.

Traffic Crashes by Ramp: I-75 (M-15 to Oakland County Line)

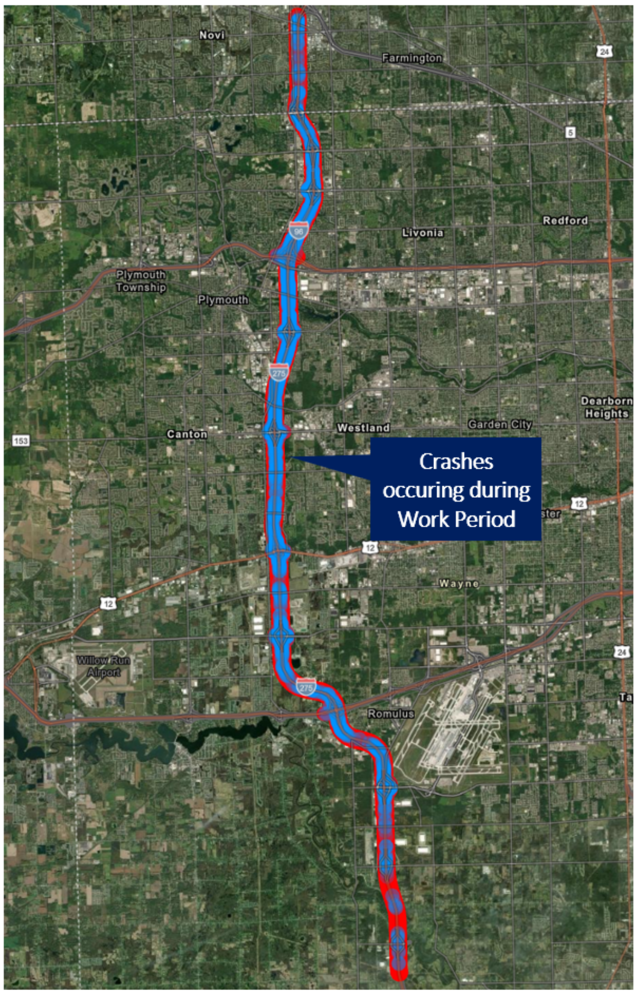
Ramp Information			Average AADT	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.		Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
SB Exit Ramp to Grange Hall Rd	0.297	SB	1,064	1,826	14	0	207	0	0	0.008	0.000
Grange Hall Rd SB Entrance Ramp	0.187	SB	4,272	1,826	6	0	207	0	0	0.003	0.000
SB Exit Ramp to Holly Rd	0.228	SB	1,368	1,826	4	0	207	0	0	0.002	0.000
Holly Rd SB Entrance Ramp	0.373	SB	2,393	1,826	3	0	207	0	0	0.002	0.000
SB Exit Ramp to Dixie Hwy	0.251	SB	6,338	1,826	230	0	207	17	0	0.126	0.082
SB Dixie Hwy SB Entrance Ramp	0.163	SB	3,985	1,826	7	0	207	0	0	0.004	0.000
NB Dixie Hwy SB Entrance Ramp	0.381	SB	2,794	1,826	3	0	207	0	0	0.002	0.000
SB Exit Ramp to M-15	0.344	SB	2,113	1,826	9	0	207	0	0	0.005	0.000
SB M-15 SB Entrance Ramp	0.260	SB	6,629	1,826	2	0	207	0	0	0.001	0.000
NB M-15 SB Entrance Ramp	0.394	NB	2,580	1,826	2	0	207	0	0	0.001	0.000
NB Exit Ramp to M-15	0.374	NB	8,841	1,826	24	0	207	3	0	0.013	0.014
NB M-15 NB Entrance Ramp	0.253	NB	908	1,826	0	0	207	0	0	0.000	0.000
SB M-15 NB Entrance Ramp	0.483	NB	1,143	1,826	1	0	207	0	0	0.001	0.000
NB Exit Ramp to Dixie Hwy	0.204	NB	7,502	1,826	33	0	207	4	0	0.018	0.019
NB Dixie Hwy NB Entrance Ramp	0.134	NB	5,477	1,826	15	0	207	0	0	0.008	0.000
SB Dixie Hwy NB Entrance Ramp	0.218	NB	315	1,826	0	0	207	0	0	0.000	0.000
NB Exit Ramp to Holly Rd	0.231	NB	2,346	1,826	3	0	207	0	0	0.002	0.000
Holly Rd NB Entrance Ramp	0.139	NB	1,453	1,826	5	0	207	0	0	0.003	0.000
NB Exit Ramp to Grange Hall Rd	0.319	NB	3,974	1,826	8	0	207	1	0	0.004	0.005
Grange Hall Rd NB Entrance Ramp	0.181	NB	1,003	1,826	11	0	207	0	0	0.006	0.000
All Ramps	5.416	-	3,325	36,520	380	0	4,140	25	0	0.010	0.006

Work Zone Traffic Crashes by Circumstance: I-75 (M-15 to Oakland County Line)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	2	0.5%
	Vehicle(s) Struck Channelizing Devices	7	1.6%
	Sideswipe Same Collisions Related to Lane Closure	0	0.0%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	83	19.4%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	26	6.1%
	Vehicle(s) Entered Work Area	1	0.2%
	Collisions involving Work Vehicles	0	0.0%
	Collisions involving Workers	0	0.0%
	Other Work Zone Related Motor Vehicle Crashes	1	0.2%
	All Motor Vehicle Crashes Directly Related to Work Zone	**120**	**28.1%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	87	20.4%
	Other Sideswipe Same Collisions	93	21.8%
	Other Rear End Collisions	73	17.1%
	Rear End Collisions at Ramp Termini	20	4.7%
	Vehicles Striking Loose Objects on Roadway	15	3.5%
	Vehicles Struck Pedestrian on Freeway	0	0.0%
	Vehicles Struck Pedestrian at Ramp Termini	0	0.0%
	Vehicles Struck Bicyclist at Ramp Termini	0	0.0%
	Other Motor Vehicle Crashes	19	4.4%
	All Other Motor Vehicle Crashes	**307**	**71.9%**
	Total	**427**	**100.0%**

A.23 Reconstruction Project along I-275 (M-153 to 5 Mile Road)

The urban freeway project shown in the map below included approximately 23.2 miles of reconstruction work along I-275 in Wayne County. The work was primarily completed via a series of crossovers during the 2021-2023 construction seasons, with work ongoing beyond the 2016-2023 study period. It should also be noted that there were limitations in identifying the timing of specific stages and associated temporary traffic control configurations. This primarily impacted the ability to disaggregate beyond analyzing each construction season as a single phase as well as the location of transition and termination areas.



Map of I-275 (M-153 to 5 Mile Road) Reconstruction Project

Aside from the COVID-19 pandemic, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2021. Therefore, data from 2016-2019 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: I-275 (M-153 to 5 Mile Road)

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	68,363	53,395	901,665,334	769	133	62	8.1%	85.3	14.8	6.9
2017	69,200	53,431	901,285,249	976	194	17	1.7%	108.3	21.5	1.9
2018	68,599	51,663	898,053,338	900	138	4	0.4%	100.2	15.4	0.4
2019	66,895	52,344	888,637,693	964	181	7	0.7%	108.5	20.4	0.8
2020	52,908	41,328	700,863,054	426	72	8	1.9%	60.8	10.3	1.1
2021	63,209	48,424	813,916,734	773	147	249	32.2%	95.0	18.1	30.6
2022	57,942	46,780	783,223,772	987	161	557	56.4%	126.0	20.6	71.1
2023	59,654	48,039	804,208,837	838	139	491	58.6%	104.2	17.3	61.1
All Years	**63,346**	**49,425**	**6,691,854,011**	**6,633**	**1,165**	**1,395**	**21.0%**	**99.1**	**17.4**	**20.8**

Traffic crash rates during the work period across the entire corridor (117.8) were slightly larger than what is typically observed during a typical year with no construction activity (100.5 for the years 2016 to 2019). The crash rate observed during a typical construction-season under normal operations along this corridor was slightly lower (94.9), where the corridor experienced a higher rate of single vehicle, rear end and sideswipe same collisions during the work period.

Summary of Work Zone Traffic Crash and Volume Data: I-275 (M-153 to 5 Mile Road)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Construction 2021	7/7/2021	12/15/2021	162	Reconstruction Work	361,245,235	496	81	247	49.8%	137.3	22.4	68.4
Winter 2021	12/16/2021	2/21/2022	68	All Lanes Open	145,915,923	122	20	0	0.0%	83.6	13.7	0.0
Construction 2022	2/22/2022	12/31/2022	313	Reconstruction Work	671,642,409	880	143	557	63.3%	131.0	21.3	82.9
Construction 2023	1/1/2023	12/31/2023	365	Reconstruction Work	804,209,515	838	139	491	58.6%	104.2	17.3	61.1
All Stages	**7/7/2021**	**12/31/2023**	**908**		**1,983,013,082**	**2,336**	**383**	**1,295**	**55.4%**	**117.8**	**19.3**	**65.3**

Crash Rates by Worst Injury/ Type: I-275 (M-153 to 5 Mile Road) – *Excludes Winter Shutdown*

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.4	0.1
Severe Injury (A)	0.8	1.0
Minor Injury (B)	3.8	5.0
Possible Injury (C)	12.1	13.7
Property Damge Only	77.9	100.8
Total	**94.9**	**120.5**

Crash Type	Normal Operations	All Stages
Single Vehicle	13.9	21.9
Head On	0.1	0.1
Angle	0.6	0.1
Rear End	54.1	59.1
Sideswipe Same	21.3	35.2
Sideswipe Opposite	0.2	0.0
Other	4.8	4.3
Total	**94.9**	**120.5**

Overall, approximately 372.0 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations. This represents an increase of approximately 18.9 percent. This was primarily driven by degraded performance within the activity areas in both directions of I-275.

Total Traffic Crashes by Stage: I-275 (M-153 to 5 Mile Road)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Construction 2021	Reconstruction Work	7/7/2021	12/15/2021	162	313.2	354.6	355.1	496.0	+140.9	39.7%
Winter 2021	All Lanes Open	12/16/2021	2/21/2022	68	157.1	170.3	170.6	122.0	-48.6	-28.5%
Construction 2022	Reconstruction Work	2/22/2022	12/31/2022	313	544.2	631.9	631.6	880.0	+248.4	39.3%
Construction 2023	Reconstruction Work	1/1/2023	12/31/2023	365	770.5	802.8	806.7	838.0	+31.3	3.9%
All Stages		7/7/2021	12/31/2023	908	1,784.9	1,959.6	1,964.0	2,336.0	+372.0	18.9%

Total Traffic Crashes by Area: I-275 (M-153 to 5 Mile Road)

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
I-275 NB	Upstream	21,365	8.2	5.8	6.4	13.0	+6.6	102.1%
	Advance Warning	21,754	19.8	10.9	12.9	27.0	+14.1	109.6%
	Activity	49,451	575.7	642.9	643.7	954.0	+310.3	48.2%
	Downstream	83,299	76.5	132.0	130.0	74.0	-56.0	-43.1%
All Northbound Areas		43,967	680.2	791.5	793.0	1,068.0	+275.0	34.7%
I-275 SB	Upstream	77,842	54.6	55.8	55.8	24.0	-31.8	-57.0%
	Advance Warning	80,085	228.1	216.2	216.6	200.0	-16.6	-7.7%
	Activity	58,824	646.7	713.0	714.6	884.0	+169.4	23.7%
	Downstream	34,221	18.2	12.8	13.4	38.0	+24.6	182.8%
All Soundbound Areas		62,743	947.6	997.8	1,000.4	1,146.0	+145.6	14.5%

In general, there were not major changes in safety performance along the ramps impacted by the work. Given the review of each UD-10 report form diagram and narrative, the most common circumstance directly related to work zone temporary traffic control was rear end collisions related to vehicles stopping or slowing.

Work Zone Traffic Crashes by Circumstance: I-275 (M-153 to 5 Mile Road)

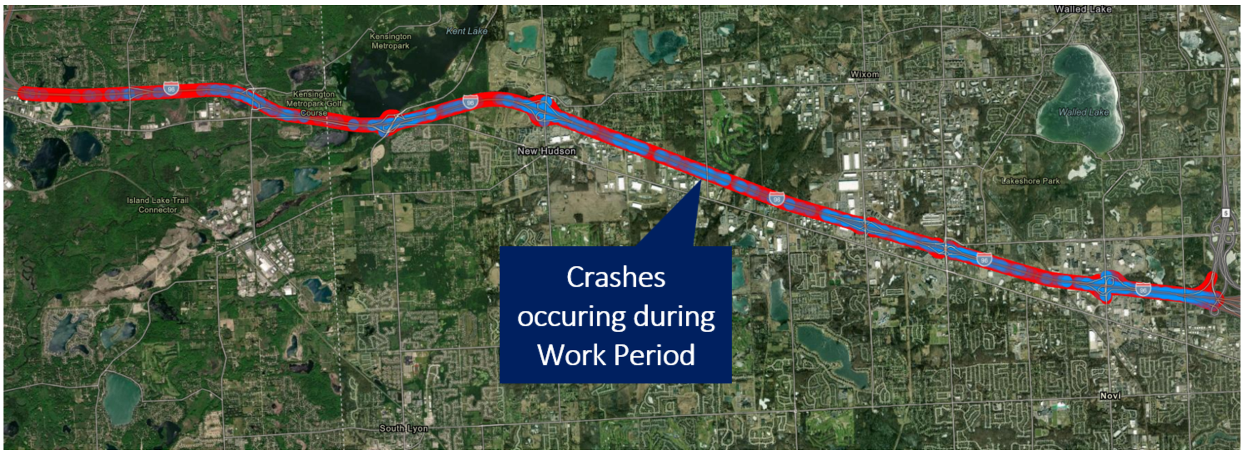
Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	4	0.2%
	Vehicle(s) Struck Channelizing Devices	26	1.0%
	Sideswipe Same Collisions Related to Lane Closure	24	0.9%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	713	27.2%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	17	0.6%
	Vehicle(s) Entered Work Area	4	0.2%
	Collisions involving Work Vehicles	11	0.4%
	Collisions involving Workers	1	0.0%
	Other Work Zone Related Motor Vehicle Crashes	19	0.7%
	All Motor Vehicle Crashes Directly Related to Work Zone	**819**	**31.3%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	402	15.3%
	Other Sideswipe Same Collisions	653	24.9%
	Other Rear End Collisions	457	17.4%
	Rear End Collisions at Ramp Termini	99	3.8%
	Vehicles Striking Loose Objects on Roadway	64	2.4%
	Vehicles Struck Pedestrian on Freeway	1	0.0%
	Vehicles Struck Pedestrian at Ramp Termini	2	0.1%
	Vehicles Struck Bicyclist at Ramp Termini	2	0.1%
	Other Motor Vehicle Crashes	121	4.6%
	All Other Motor Vehicle Crashes	**1,801**	**68.7%**
	Total	**2,620**	**100.0%**

Traffic Crashes by Ramp: I-275 (M-153 to 5 Mile Road)

Ramp Information			Average	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.	AADT	Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
NB Exit to Eureka Rd	0.418	NB	3,333	1,461	9	0	908	11	0	0.006	0.012
EB Eureka Rd NB Entrance Ramp	0.295	NB	1,219	1,461	2	0	908	0	0	0.001	0.000
WB Eureka Rd NB Entrance Ramp	0.383	NB	10,526	1,461	6	0	908	3	1	0.004	0.003
NB Exit to I-94	0.228	NB	11,662	1,461	2	0	908	4	3	0.001	0.004
I-94 NB Entrance Ramp	0.148	NB	22,518	1,461	2	0	908	2	1	0.001	0.002
NB Exit Ramp to Ecorse Rd	0.434	NB	10,891	1,461	5	0	908	8	2	0.003	0.009
Ecorse Rd NB Entrance Ramp	0.360	NB	5,691	1,461	7	0	908	5	4	0.005	0.006
NB Exit to US-12	0.400	NB	8,633	1,461	18	0	908	12	2	0.012	0.013
EB US-12 NB Entrance Ramp	0.201	NB	8,922	1,461	2	0	908	1	1	0.001	0.001
WB US-12 NB Entrance Ramp	0.310	NB	6,577	1,461	8	0	908	3	1	0.005	0.003
NB Exit Ramp to Ford Rd	0.412	NB	10,665	1,461	36	0	908	9	0	0.025	0.010
EB Ford Rd NB Entrance Ramp	0.236	NB	10,428	1,461	5	0	908	4	0	0.003	0.004
WB Ford Rd NB Entrance Ramp	0.405	NB	8,965	1,461	7	0	908	3	2	0.005	0.003
NB Exit to Ann Arbor Rd	0.365	NB	8,153	1,461	19	0	908	10	1	0.013	0.011
EB Ann Arbor Rd NB Entrance Ramp	0.223	NB	8,834	1,461	5	1	908	3	1	0.003	0.003
WB Ann Arbor Rd NB Entrance Ramp	0.330	NB	6,050	1,461	4	0	908	4	1	0.003	0.004
NB Exit to I-96	0.177	NB	21,331	1,461	0	0	908	0	0	0.000	0.000
M-14 NB Entrance Ramp	0.202	NB	18,225	1,461	4	0	908	5	2	0.003	0.006
I-96 NB Entrance Ramp	0.511	NB	10,000	1,461	18	0	908	13	2	0.012	0.014
SB Exit Ramp to 6 Mile Rd	0.399	SB	9,143	1,461	35	0	908	28	0	0.024	0.031
WB 6 Mile Rd SB Entrance Ramp	0.233	SB	3,770	1,461	5	0	908	3	0	0.003	0.003
EB 6 Mile Rd SB Entrance Ramp	0.366	SB	4,977	1,461	5	1	908	3	0	0.003	0.003
SB Exit Ramp to I-96	0.740	SB	38,960	1,461	9	0	908	9	3	0.006	0.010
SB Exit Ramp to M-14	0.524	SB	19,890	1,461	10	0	908	6	1	0.007	0.007
WB M-14 SB Entrance Ramp	0.256	SB	15,677	1,461	22	0	908	8	0	0.015	0.009
EB M-14 SB Entrance Ramp	0.386	SB	6,015	1,461	9	0	908	11	2	0.006	0.012
SB Exit Ramp to Ann Arbor Rd	0.378	SB	12,773	1,461	52	0	908	17	2	0.036	0.019
WB Ann Arbor Rd SB Entrance Ramp	0.243	SB	4,292	1,461	1	0	908	1	0	0.001	0.001
EB Ann Arbor Rd SB Entrance Ramp	0.375	SB	5,285	1,461	1	0	908	5	0	0.001	0.006
SB Exit Ramp to Ford Rd	0.377	SB	18,712	1,461	79	0	908	25	3	0.054	0.028
WB Ford Rd SB Entrance Ramp	0.247	SB	4,933	1,461	3	0	908	2	1	0.002	0.002
EB Ford Rd SB Entrance Ramp	0.318	SB	6,150	1,461	9	0	908	6	2	0.006	0.007
SB Exit Ramp to US-12	0.386	SB	15,802	1,461	66	0	908	34	1	0.045	0.037
WB US-12 SB Entrance Ramp	0.252	SB	3,422	1,461	5	0	908	0	0	0.003	0.000
EB US-12 SB Entrance Ramp	0.264	SB	5,073	1,461	4	0	908	2	1	0.003	0.002
SB Exit Ramp to Ecorse Rd	0.401	SB	7,004	1,461	12	0	908	9	1	0.008	0.010
Ecorse Rd SB Entrance Ramp	0.377	SB	5,564	1,461	6	0	908	4	2	0.004	0.004
SB Exit Ramp to I-94	0.449	SB	21,217	1,461	9	0	908	2	1	0.006	0.002
WB I-94 SB Entrance Ramp	0.267	SB	6,740	1,461	15	0	908	3	0	0.010	0.003
EB I-94 SB Entrance Ramp	0.476	SB	8,101	1,461	5	0	908	6	0	0.003	0.007
All Ramps	**13.757**	**-**	**10,403**	**58,440**	**521**	**2**	**36,320**	**284**	**44**	**0.009**	**0.008**

A.24 Flex Route Project along I-96 (Kent Lake to I-275)

The urban freeway project shown in the map below included approximately 11.8 miles of reconstruction work in addition to the installation of the "Flex Route" active traffic management system. The work was completed primarily via a series of crossovers beginning in 2022 and extending beyond the 2016-2023 study period. It should also be noted that there were limitations in identifying the timing of specific stages and associated temporary traffic control configurations. This primarily impacted the ability to disaggregate beyond analyzing each construction season as a single phase as well as the location of transition and termination areas. Additionally, the eastbound end of the study corridor was truncated at the end of the I-96.



Map of I-96 (Kent Lake to I-275) Flex Route Project

Aside from the COVID-19 pandemic, traffic crash and volume data were relatively consistent prior to the implementation of work zone temporary traffic control in 2022. Therefore, data from 2016-2019 and 2021 were considered to be under normal operations from a work zone perspective.

Summary of Traffic Crash and Volume Data: I-96 (Kent Lake to I-275)

Year	Average EB AADT	Average WB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	61,343	63,407	650,364,946	572	122	15	2.6%	88.0	18.8	2.3
2017	61,343	63,407	648,587,992	601	122	7	1.2%	92.7	18.8	1.1
2018	60,995	62,427	642,007,334	524	123	8	1.5%	81.6	19.2	1.2
2019	61,058	61,619	641,607,770	628	125	4	0.6%	97.9	19.5	0.6
2020	49,362	50,749	520,813,210	347	74	19	5.5%	66.6	14.2	3.6
2021	56,901	64,059	624,032,097	404	94	3	0.7%	64.7	15.1	0.5
2022	52,172	61,420	584,511,657	565	107	264	46.7%	96.7	18.3	45.2
2023	53,990	63,201	602,920,886	812	150	518	63.8%	134.7	24.9	85.9
All Years	**57,146**	**61,286**	**4,914,845,893**	**4,453**	**917**	**838**	**18.8%**	**90.6**	**18.7**	**17.1**

Traffic crash rates during the work period across the entire corridor (119.5) were considerably larger than what is typically observed during a typical year with no construction activity (85.1 for the years 2016 to 2019 and 2021). The crash rate observed during a typical construction-season under normal operations along this corridor was slightly lower (80.9), where the corridor experienced a higher rate of single vehicle, rear end and sideswipe same collisions during the work period. It is worth noting that the rate of rear end collisions nearly doubled during the work period.

Summary of Work Zone Traffic Crash and Volume Data: I-96 (Kent Lake to I-275)

Stage Information				Description	VMT	Crashes		Work Zone Coded		Crash Rate		
Stages	Start	End	Days			Total	FI	Count	Share	Total	FI	WZ Coded
Construction 2022	3/21/2022	11/8/2022	233	Reconstruction Work	373,126,620	397	85	259	65.2%	106.4	22.8	69.4
Winter 2022	11/9/2022	3/5/2023	117	All Lanes Open	193,265,051	164	35	9	5.5%	84.9	18.1	4.7
Construction 2023	3/6/2023	12/4/2023	274	Reconstruction Work	452,603,624	681	125	506	74.3%	150.5	27.6	111.8
Winter 2023	12/5/2023	12/31/2023	27	All Lanes Open	44,599,627	29	2	7	24.1%	65.0	4.5	15.7
All Stages	**3/21/2022**	**12/31/2023**	**651**		**1,063,594,921**	**1,271**	**247**	**781**	**61.4%**	**119.5**	**23.2**	**73.4**

Crash Rates by Worst Injury and Type: I-96 (Kent Lake to I-275) – *Excludes Winter Shutdown*

Worst Injury in Crash	Normal Operations	All Stages
Fatal	0.2	0.1
Severe Injury (A)	1.3	1.6
Minor Injury (B)	3.4	6.1
Possible Injury (C)	12.8	17.7
Property Damge Only	63.3	105.1
Total	**80.9**	**130.6**

Crash Type	Normal Operations	All Stages
Single Vehicle	15.0	20.2
Head On	0.1	0.2
Angle	0.2	0.0
Rear End	43.3	80.9
Sideswipe Same	17.6	25.7
Sideswipe Opposite	0.0	0.0
Other	4.7	3.5
Total	**80.9**	**130.6**

Overall, approximately 355.3 additional traffic crashes are estimated to have occurred across the corridor during the study work period than would have been expected under normal operations. This represents an increase of approximately 38.8 percent. This was primarily driven by severely degraded performance within the activity areas in both directions of I-275. While performance was severely degraded along each direction of I-275, the eastbound direction experienced approximately 77.3 percent more collisions during the study work period than would have been expected under normal operations.

Total Traffic Crashes by Stage: I-96 (Kent Lake to I-275)

Stage Information					Crashes during Normal Operations			Crashes during Work Zone Operations		
Stages	Description	Start	End	Days	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
Construction 2022	Reconstruction Work	3/21/2022	11/8/2022	233	316.1	303.6	305.1	397.0	+91.9	30.1%
Winter 2022	All Lanes Open	11/9/2022	3/5/2023	117	215.1	191.3	195.3	164.0	-31.3	-16.0%
Construction 2023	Reconstruction Work	3/6/2023	12/4/2023	274	393.2	367.9	370.2	681.0	+310.8	83.9%
Winter 2023	All Lanes Open	12/5/2023	12/31/2023	27	49.6	44.1	45.1	29.0	-16.1	-35.6%
All Stages		**3/21/2022**	**12/31/2023**	**651**	**974.1**	**906.9**	**915.7**	**1,271.0**	**+355.3**	**38.8%**

Total Traffic Crashes by Area: I-96 (Kent Lake to I-275)

Segment Information			Crashes during Normal Operations			Crashes during Work Zone Operations		
Route	Area	Average AADT	Predicted from Similar Sites	Observed	Expected	Observed	Estimated Change	Percent Change
I-96 EB	Upstream	43,778	15.0	3.9	4.8	8.0	+3.2	65.0%
I-96 EB	Advance Warning	45,848	45.6	45.8	45.8	88.0	+42.2	92.1%
I-96 EB	Activity	55,364	283.0	301.0	300.2	526.0	+225.8	75.2%
All Eastbound Areas		**48,330**	**343.5**	**350.6**	**350.9**	**622.0**	**+271.1**	**77.3%**
I-96 WB	Activity	63,897	344.7	320.9	323.1	456.0	+132.9	41.1%
I-96 WB	Downstream	52,792	21.1	0.0	1.4	0.0	-1.4	-100.0%
All Westbound Areas		**58,344**	**365.8**	**320.9**	**324.5**	**456.0**	**+131.5**	**40.5%**

In general, there were not major changes in safety performance along the ramps impacted by the work. Given the review of each UD-10 report form diagram and narrative, the most common circumstance directly related to work zone temporary traffic control was rear end collisions related to vehicles stopping or slowing.

Traffic Crashes by Ramp: I-96 (Kent Lake to I-275)

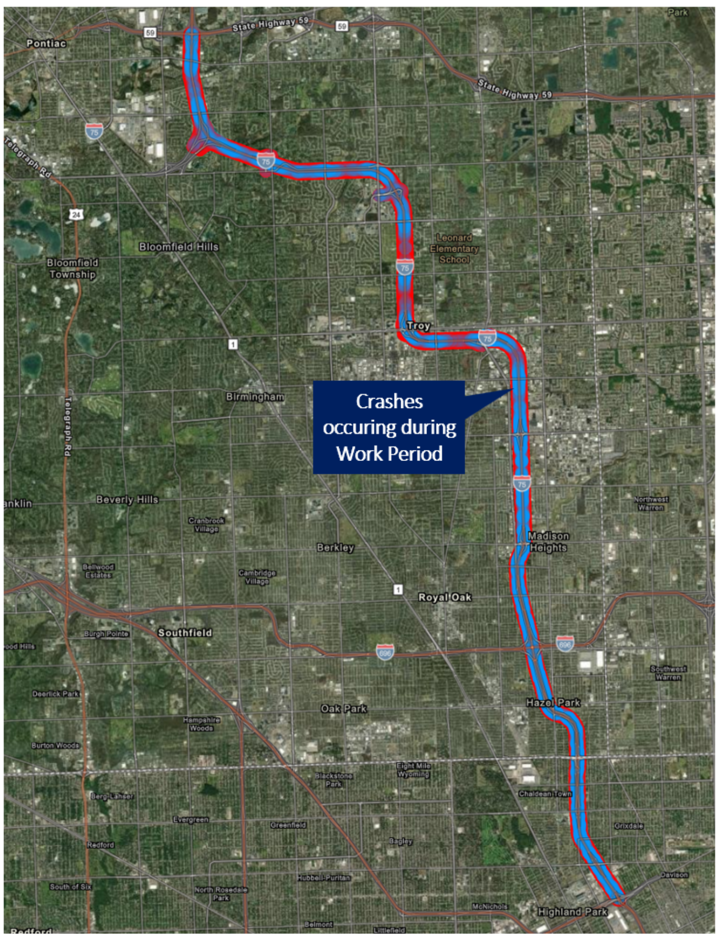
Ramp Information			Average AADT	Normal Operations			All Stages			Crashes per Day	
Description	Length	Dir.		Days	Total	WZ Coded	Days	Total	WZ Coded	Normal	All Stages
SB M-5 WB Entrance Ramp	0.434	WB	7,795	1,826	2	0	651	0	0	0.001	0.000
WB Exit Ramp to Novi Rd	0.472	WB	13,955	1,826	88	0	651	21	3	0.048	0.032
NB Novi Rd WB Entrance Ramp	0.317	WB	3,314	1,826	14	0	651	1	0	0.008	0.002
SB Novi Rd WB Entrance Ramp	0.221	WB	3,425	1,826	13	0	651	0	0	0.007	0.000
WB Exit Ramp to Beck Rd	0.340	WB	12,842	1,826	18	0	651	6	0	0.010	0.009
Beck Rd WB Entrance Ramp	0.150	WB	6,549	1,826	5	0	651	0	0	0.003	0.000
WB Exit Ramp to Wixom Rd	0.374	WB	15,835	1,826	8	0	651	3	0	0.004	0.005
Wixom Rd WB Entrance Ramp	0.369	WB	6,072	1,826	9	0	651	1	0	0.005	0.002
WB Exit Ramp to NB Milford Rd	0.377	WB	5,783	1,826	109	0	651	8	0	0.060	0.012
WB Exit Ramp to SB Milford Rd	0.262	WB	4,270	1,826	74	0	651	7	0	0.041	0.011
Milford Rd WB Entrance Ramp	0.352	WB	6,493	1,826	9	0	651	1	1	0.005	0.002
WB Exit Ramp to Kent Lake Rd	0.269	WB	2,660	1,826	4	0	651	0	0	0.002	0.000
Kent Lake Rd WB Entrance Ramp	0.304	WB	2,730	1,826	6	0	651	0	0	0.003	0.000
EB Exit Ramp to Kent Lake Rd	0.200	EB	2,710	1,826	6	0	651	7	2	0.003	0.011
SB Kent Lake Rd EB Entrance Ramp	0.153	EB	206	1,826	0	0	480	0	0	0.000	0.000
NB Kent Lake EB Entrance Ramp	0.299	EB	2,287	1,826	2	0	480	0	0	0.001	0.000
EB Exit Ramp to Milford Rd	0.326	EB	6,007	1,826	27	0	480	5	0	0.015	0.010
SB Milford Rd EB Entrance Ramp	0.271	EB	4,974	1,826	8	0	480	2	2	0.004	0.004
NB Milford Rd EB Entrance Ramp	0.281	EB	4,313	1,826	6	0	480	0	0	0.003	0.000
EB Exit Ramp to Wixom Rd	0.213	EB	5,491	1,826	6	0	480	1	0	0.003	0.002
Wixom Rd EB Entrance Ramp	0.201	EB	12,445	1,826	3	0	485	1	0	0.002	0.002
EB Exit Ramp to Beck Rd	0.297	EB	5,927	1,826	4	0	533	1	0	0.002	0.002
Beck Rd EB Entrance Ramp	0.355	EB	12,157	1,826	33	0	535	4	1	0.018	0.007
EB Exit Ramp to Novi Rd	0.384	EB	5,704	1,826	43	1	554	14	1	0.024	0.025
SB Novi Rd EB Entrance Ramp	0.212	EB	5,214	1,826	3	0	503	0	0	0.002	0.000
NB Novi Rd EB Entrance Ramp	0.417	EB	7,400	1,826	11	0	571	0	0	0.006	0.000
EB I-96 Ramp	0.437	EB	36,389	1,826	51	3	651	27	20	0.028	0.041
All Ramps	**8.287**	**-**	**7,517**	**49,302**	**562**	**4**	**15,826**	**110**	**30**	**0.011**	**0.007**

Work Zone Traffic Crashes by Circumstance: I-96 (Kent Lake to I-275)

Circumstance		Count	Share
Common Work Zone Crash Scenarios	Vehicle(s) Struck Temporary Traffic Control	1	0.1%
	Vehicle(s) Struck Channelizing Devices	7	0.5%
	Sideswipe Same Collisions Related to Lane Closure	11	0.8%
	Rear End Collisions Related to Vehicles Stopping or Slowing in Work Zone	525	38.0%
	Other Collisions Related to Vehicles Stopping or Slowing in Work Zone	16	1.2%
	Vehicle(s) Entered Work Area	1	0.1%
	Collisions involving Work Vehicles	8	0.6%
	Collisions involving Workers	0	0.0%
	Other Work Zone Related Motor Vehicle Crashes	9	0.7%
	All Motor Vehicle Crashes Directly Related to Work Zone	**578**	**41.9%**
Other Motor Vehicle Crashes in Work Zone	Other Single Vehicle Lane Departure Crashes	181	13.1%
	Other Sideswipe Same Collisions	259	18.8%
	Other Rear End Collisions	225	16.3%
	Rear End Collisions at Ramp Termini	46	3.3%
	Vehicles Striking Loose Objects on Roadway	31	2.2%
	Vehicles Struck Pedestrian on Freeway	0	0.0%
	Vehicles Struck Pedestrian at Ramp Termini	0	0.0%
	Vehicles Struck Bicyclist at Ramp Termini	0	0.0%
	Other Motor Vehicle Crashes	61	4.4%
	All Other Motor Vehicle Crashes	**803**	**58.1%**
	Total	**1,381**	**100.0%**

A.25 Modernization Project along I-75 (8 Mile Road to South Boulevard)

The urban freeway project shown in the map below included approximately 18 miles of modernization work along I-75 as it runs north of Detroit into southern Oakland County. This modernization work was primarily constructed via three phases, where the northern portion of the corridor (from South Boulevard to Coolidge Highway) represented the first segment completed during 2016 and 2017. Next, the middle portion of the corridor (from Coolidge Highway to 13 Mile Road) was completed between 2018 and 2020. Finally, the third segment along the southern portion of the corridor (13 Mile Road to Eight Mile Road) was completed between 2019 and 2023. Given the nature of this complex effort that occurred across the entire study period, it was not possible to employ the same analytical approach as the other 24 projects. Instead, an overview of the safety performance observed across the corridor during the study period is provided. This analysis extended beyond the work area to consider advance warning and upstream areas, from M-59 to the north and M-8 to the south.



Map of I-75 (8 Mile Road to South Boulevard) Modernization Project

A summary of the annual traffic crash and volume data along the corridor is presented below. First, it is critical to recognize that the crash rates observed along the corridor (173.5) are considerably higher than any other corridor evaluated as a part of OR23-022. These crash rates are approximately 47 percent greater than the other two high-volume projects along I-96 and I-275. In other words, the safety performance observed along this corridor (both under normal operations as well as during the modernization work) represents a unique scenario that should not be directly compared to typical MDOT freeway projects. It should also be noted that the UD-10 crash report forms were not reviewed for this project.

Summary of Traffic Crash and Volume Data: I-75 (8 Mile Road to South Boulevard)

Year	Average SB AADT	Average NB AADT	Total VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
2016	67,103	73,851	1,047,738,256	1,996	461	121	6.1%	190.5	44.0	11.5
2017	67,103	73,851	1,044,875,583	2,010	448	116	5.8%	192.4	42.9	11.1
2018	66,448	71,467	1,026,388,386	1,940	412	134	6.9%	189.0	40.1	13.1
2019	63,292	66,483	940,821,247	1,658	360	581	35.0%	176.2	38.3	61.8
2020	41,069	47,666	663,180,965	953	228	369	38.7%	143.7	34.4	55.6
2021	39,492	53,818	700,509,819	1,126	262	543	48.2%	160.7	37.4	77.5
2022	38,677	55,295	708,279,279	1,266	289	404	31.9%	178.7	40.8	57.0
2023	73,427	62,788	994,372,801	1,414	271	348	24.6%	142.2	27.3	35.0
All Years	**57,077**	**63,152**	**7,126,166,336**	**12,363**	**2,731**	**2,616**	**21.2%**	**173.5**	**38.3**	**36.7**

Traffic crash rates were highest during Segment 1, despite the fact that this represented the lowest share of work zone-coded crashes. This is in part due to the fact that the corridor served the largest total number of vehicles during this period before construction efforts began to considerably reduce capacity. Crash rates declined significantly as the share of work zone-coded crashes increased. In other words, as the relative intensity of work activity increased (and capacity was reduced below the 140,000 vehicles per day that was observed earlier in the study period), crash rates across the corridor tended to decrease despite the work activity. The highest share (and rate) of work zone-coded crashes was observed during 2021 as Segment 3 activities were underway. Fatal and injury crash rates generally followed similar trends.

Traffic crash rates for each segment are presented below for reference, including total crashes, fatal and injury crashes, as well as work zone-coded crashes. Traffic crash rates by worst injury and crash type are also provided. Finally, traffic crash data specific to the study period for the ramps along the corridor are provided but it should be noted that limited information was available to determine when closures (or interchange modifications) may have occurred.

Traffic Crash Rates by Segment: I-75 (8 Mile Road to South Boulevard)

Area		Length	VMT	Crashes		Work Zone Coded		Crash Rate per 100M VMT		
				Total	FI	Count	Share	Total	FI	WZ Coded
	M-59 to Square Lake	2.01	357,006,766	426	96	63	14.8%	119.3	26.9	17.6
	Square Lake to Adams	1.26	166,440,970	127	26	21	16.5%	76.3	15.6	12.6
	Adams to Crooks	2.55	330,868,910	352	76	93	26.4%	106.4	23.0	28.1
	Crooks to Big Beaver	2.64	337,701,175	314	72	70	22.3%	93.0	21.3	20.7
	Big Beaver to Rochester	1.52	217,164,180	151	31	36	23.8%	69.5	14.3	16.6
	Rochester to 14 Mile	2.22	388,808,439	334	74	76	22.8%	85.9	19.0	19.5
	14 Mile to 12 Milie	2.03	408,774,370	543	124	182	33.5%	132.8	30.3	44.5
NB I-75	12 Mile to 11 Mile	0.99	207,331,801	529	109	171	32.3%	255.1	52.6	82.5
	11 Mile to I-696	0.99	208,353,339	573	132	155	27.1%	275.0	63.4	74.4
	I-696 to 9 Mile	1.09	221,167,292	885	203	207	23.4%	400.1	91.8	93.6
	9 Mile to 8 Mile	1.29	253,083,170	587	155	151	25.7%	231.9	61.2	59.7
	8 Mile to 7 Mile	0.98	215,594,026	485	115	70	14.4%	225.0	53.3	32.5
	7 Mile to McNichols	1.10	247,333,441	765	166	32	4.2%	309.3	67.1	12.9
	McNichols to M-8	0.74	171,623,155	268	43	19	7.1%	156.2	25.1	11.1
	All Northbound Areas	**21.40**	**3,731,251,034**	**6,339**	**1,422**	**1,346**	**21.2%**	**169.9**	**38.1**	**36.1**
	M-59 to Square Lake	1.96	348,887,414	381	72	80	21.0%	109.2	20.6	22.9
	Square Lake to Adams	1.33	179,169,019	171	41	24	14.0%	95.4	22.9	13.4
	Adams to Crooks	2.52	333,955,737	313	69	84	26.8%	93.7	20.7	25.2
	Crooks to Big Beaver	2.61	334,461,739	234	59	54	23.1%	70.0	17.6	16.1
	Big Beaver to Rochester	1.57	194,426,824	187	29	34	18.2%	96.2	14.9	17.5
	Rochester to 14 Mile	2.19	306,928,461	710	141	210	29.6%	231.3	45.9	68.4
	14 Mile to 12 Milie	2.04	340,994,634	694	143	249	35.9%	203.5	41.9	73.0
SB I-75	12 Mile to 11 Mile	1.00	184,167,492	726	176	120	16.5%	394.2	95.6	65.2
	11 Mile to I-696	0.98	180,446,865	588	122	120	20.4%	325.9	67.6	66.5
	I-696 to 9 Mile	1.11	197,102,725	420	85	110	26.2%	213.1	43.1	55.8
	9 Mile to 8 Mile	1.29	222,502,865	563	158	101	17.9%	253.0	71.0	45.4
	8 Mile to 7 Mile	0.99	194,845,296	350	62	36	10.3%	179.6	31.8	18.5
	7 Mile to McNichols	1.07	216,874,726	384	84	33	8.6%	177.1	38.7	15.2
	McNichols to M-8	0.76	160,151,506	303	68	15	5.0%	189.2	42.5	9.4
	All Southbound Areas	**21.41**	**3,394,915,302**	**6,024**	**1,309**	**1,270**	**21.1%**	**177.4**	**38.6**	**37.4**

Traffic Crash Rates by Worst Injury and Segment: I-75 (8 Mile Road to South Boulevard)

Area		Length	VMT	Crash Rate per 100M VMT				
				Fatal	Serious	Minor	Possible	PDO
	M-59 to Square Lake	2.01	357,006,766	0.28	0.00	9.52	17.09	92.44
	Square Lake to Adams	1.26	166,440,970	0.00	1.80	6.61	7.21	60.68
	Adams to Crooks	2.55	330,868,910	0.60	1.21	6.04	15.11	83.42
	Crooks to Big Beaver	2.64	337,701,175	0.00	0.89	5.92	14.51	71.66
	Big Beaver to Rochester	1.52	217,164,180	0.00	0.92	5.99	7.37	55.26
	Rochester to 14 Mile	2.22	388,808,439	0.00	0.77	5.92	12.35	66.87
	14 Mile to 12 Milie	2.03	408,774,370	0.24	1.47	6.36	22.26	102.50
NB I-75	12 Mile to 11 Mile	0.99	207,331,801	0.00	0.96	11.58	40.03	202.57
	11 Mile to I-696	0.99	208,353,339	0.00	0.48	10.56	52.31	211.66
	I-696 to 9 Mile	1.09	221,167,292	0.00	4.97	13.56	73.25	308.36
	9 Mile to 8 Mile	1.29	253,083,170	0.00	3.95	19.76	37.54	170.69
	8 Mile to 7 Mile	0.98	215,594,026	0.93	3.71	9.28	39.43	171.62
	7 Mile to McNichols	1.10	247,333,441	0.00	2.02	12.13	52.96	242.18
	McNichols to M-8	0.74	171,623,155	0.00	1.75	4.66	18.65	131.10
	All Northbound Areas	**21.40**	**3,731,251,034**	**0.16**	**1.63**	**8.87**	**27.44**	**131.78**
	M-59 to Square Lake	1.96	348,887,414	0.00	1.15	6.59	12.90	88.57
	Square Lake to Adams	1.33	179,169,019	0.00	1.12	6.70	15.07	72.56
	Adams to Crooks	2.52	333,955,737	0.30	1.20	9.88	9.28	73.06
	Crooks to Big Beaver	2.61	334,461,739	0.90	0.90	4.48	11.36	52.32
	Big Beaver to Rochester	1.57	194,426,824	0.00	1.03	6.17	7.71	81.26
	Rochester to 14 Mile	2.19	306,928,461	0.65	1.95	12.05	31.28	185.39
	14 Mile to 12 Milie	2.04	340,994,634	0.00	1.47	6.74	33.72	161.59
SB I-75	12 Mile to 11 Mile	1.00	184,167,492	0.00	2.17	15.75	77.65	298.64
	11 Mile to I-696	0.98	180,446,865	0.55	1.66	12.75	52.65	258.25
	I-696 to 9 Mile	1.11	197,102,725	0.00	1.52	6.09	35.51	169.96
	9 Mile to 8 Mile	1.29	222,502,865	0.90	3.60	18.88	47.64	182.02
	8 Mile to 7 Mile	0.99	194,845,296	0.51	1.03	5.65	24.63	147.81
	7 Mile to McNichols	1.07	216,874,726	0.46	1.84	8.76	27.67	138.33
	McNichols to M-8	0.76	160,151,506	0.00	2.50	9.37	30.60	146.74
	All Southbound Areas	**21.41**	**3,394,915,302**	**0.32**	**1.59**	**9.01**	**27.63**	**138.88**

Traffic Crash Rates by Crash Type and Segment: I-75 (8 Mile Road to South Boulevard)

Area		Length	VMT	Crash Rate per 100M VMT						
				Single Vehicle	Head On	Angle	Rear End	Sideswipe Same	Sideswipe Opposite	Other
NB I-75	M-59 to Square Lake	2.01	357,006,766	33.33	0.28	3.08	44.26	31.37	0.28	6.72
	Square Lake to Adams	1.26	166,440,970	37.25	0.60	1.20	18.63	15.02	0.00	3.60
	Adams to Crooks	2.55	330,868,910	39.59	0.00	0.60	39.59	20.85	0.30	5.44
	Crooks to Big Beaver	2.64	337,701,175	31.09	0.30	0.59	32.57	23.99	0.30	4.15
	Big Beaver to Rochester	1.52	217,164,180	19.80	0.46	0.00	31.77	14.27	0.00	3.22
	Rochester to 14 Mile	2.22	388,808,439	21.86	0.26	0.00	32.15	23.92	0.00	7.72
	14 Mile to 12 Milie	2.03	408,774,370	28.38	0.00	1.96	68.74	26.91	0.00	6.85
	12 Mile to 11 Mile	0.99	207,331,801	30.39	0.48	0.96	175.56	43.89	0.00	3.86
	11 Mile to I-696	0.99	208,353,339	20.16	0.00	0.00	197.26	52.31	0.00	5.28
	I-696 to 9 Mile	1.09	221,167,292	40.69	0.00	0.90	269.93	77.77	0.00	10.85
	9 Mile to 8 Mile	1.29	253,083,170	52.16	0.79	8.30	90.09	67.17	0.00	13.43
	8 Mile to 7 Mile	0.98	215,594,026	42.21	0.00	2.78	106.22	64.01	0.46	9.28
	7 Mile to McNichols	1.10	247,333,441	80.46	0.81	6.87	128.57	76.82	0.81	14.96
	McNichols to M-8	0.74	171,623,155	33.21	0.00	0.58	54.77	54.77	0.00	12.82
	All Northbound Areas	**21.40**	**3,731,251,034**	**35.78**	**0.27**	**1.98**	**84.31**	**39.80**	**0.16**	**7.58**
SB I-75	M-59 to Square Lake	1.96	348,887,414	26.08	0.57	0.57	53.60	24.08	0.29	4.01
	Square Lake to Adams	1.33	179,169,019	44.65	0.00	2.23	24.56	20.09	0.56	3.35
	Adams to Crooks	2.52	333,955,737	36.23	0.30	0.60	27.85	21.56	0.00	7.19
	Crooks to Big Beaver	2.61	334,461,739	22.42	0.00	0.00	27.51	14.95	0.00	5.08
	Big Beaver to Rochester	1.57	194,426,824	30.35	0.00	1.03	38.57	21.09	0.00	5.14
	Rochester to 14 Mile	2.19	306,928,461	31.93	0.33	0.98	156.06	31.28	0.33	10.43
	14 Mile to 12 Milie	2.04	340,994,634	27.57	0.00	1.47	133.73	34.02	0.00	6.74
	12 Mile to 11 Mile	1.00	184,167,492	73.85	0.00	1.63	253.03	54.30	0.00	11.40
	11 Mile to I-696	0.98	180,446,865	26.05	0.00	1.11	234.97	55.97	0.00	7.76
	I-696 to 9 Mile	1.11	197,102,725	36.02	0.00	0.00	114.66	53.78	2.03	6.60
	9 Mile to 8 Mile	1.29	222,502,865	54.38	0.45	4.94	115.95	66.52	0.00	10.79
	8 Mile to 7 Mile	0.99	194,845,296	31.82	0.00	6.16	79.04	53.89	0.00	8.72
	7 Mile to McNichols	1.07	216,874,726	45.65	0.46	1.38	65.01	52.56	0.46	11.53
	McNichols to M-8	0.76	160,151,506	22.48	0.00	0.62	113.64	41.84	0.62	9.99
	All Southbound Areas	**21.41**	**3,394,915,302**	**35.05**	**0.18**	**1.47**	**96.53**	**36.41**	**0.27**	**7.54**

Traffic Crashes by Ramp: I-75 (8 Mile Road to South Boulevard)

Ramp Information			Average AADT	All Stages			Crashes per Day
Description	Length	Dir.		Days	Total	WZ Coded	
NB Exit Ramp to 8 Mile Rd	0.278	NB	13,140	2,922	11	1	0.004
8 Mile Rd NB Entrance Ramp	0.113	NB	8,591	2,922	5	0	0.002
NB Exit Ramp to 9 Mile Rd	0.133	NB	4,616	2,922	13	3	0.004
9 Mile Rd NB Entrance Ramp	0.116	NB	6,901	2,922	6	0	0.002
NB Exit Ramp to I-696	0.168	NB	26,304	2,922	42	4	0.014
I-696 NB Entrance Ramp	0.124	NB	33,860	2,922	35	6	0.012
NB Exit Ramp to 11 Mile Rd	0.159	NB	6,000	2,922	20	5	0.007
11 Mile Rd NB Entrance Ramp	0.091	NB	5,997	2,922	5	0	0.002
NB Exit Ramp to 12 Mile Rd	0.210	NB	9,442	2,922	7	1	0.002
12 Mile Rd NB Entrance Ramp	0.108	NB	4,960	2,922	4	0	0.001
NB Exit Ramp to 14 Mile Rd	0.207	NB	13,363	2,922	16	5	0.005
14 Mile Rd NB Entrance Ramp	0.205	NB	8,855	2,922	3	2	0.001
NB Exit Ramp to Rochester Rd	0.411	NB	16,001	2,922	88	5	0.030
Rochester Rd NB Entrance Ramp	0.255	NB	4,865	2,922	27	2	0.009
NB Exit Ramp to Big Beaver Rd	0.346	NB	9,131	2,922	5	0	0.002
Big Beaver Rd NB Entrance Ramp	0.277	NB	9,197	2,922	1	0	0.000
NB Exit Ramp to Crooks Rd	0.397	NB	6,226	2,922	13	1	0.004
Crooks Rd NB Entrance Ramp	0.282	NB	3,654	2,922	9	1	0.003
NB Exit Ramp to Adams Rd	0.276	NB	2,724	2,922	14	0	0.005
Adams Rd NB Entrance Ramp	0.397	NB	3,525	2,922	9	0	0.003
NB Exit Ramp to Square Lake Rd	0.503	NB	9,685	2,922	31	1	0.011
Square Lake Rd NB Entrance Ramp	0.452	NB	25,293	2,922	26	3	0.009
SB Exit Ramp to Square Lake Rd	0.585	SB	23,118	2,922	37	3	0.013
Square Lake Rd SB Entrance Ramp	0.437	SB	8,484	2,922	9	3	0.003
SB Exit Ramp to Adams Rd	0.310	SB	3,403	2,922	14	0	0.005
Adams Rd SB Entrance Ramp	0.220	SB	2,594	2,922	3	0	0.001
SB Exit Ramp to Crooks Rd	0.311	SB	3,663	2,922	12	2	0.004
Crooks Rd SB Entrance Ramp	0.463	SB	6,050	2,922	37	5	0.013
SB Exit Ramp to Big Beaver Rd	0.285	SB	8,770	2,922	2	0	0.001
Big Beaver Rd SB Entrance Ramp	0.331	SB	9,066	2,922	1	0	0.000
SB Exit Ramp to Rochester Rd	0.347	SB	6,149	2,922	10	1	0.003
Rochester Rd SB Entrance Ramp	0.205	SB	4,865	2,922	10	0	0.003
SB Exit Ramp to 14 Mile Rd	0.210	SB	6,846	2,922	13	3	0.004
14 Mile Rd SB Entrance Ramp	0.268	SB	19,017	2,922	41	6	0.014
SB Exit Ramp to 12 Mile Rd	0.214	SB	4,628	2,922	3	1	0.001
12 Mile Rd SB Entrance Ramp	0.169	SB	7,534	2,922	15	7	0.005
SB Exit Ramp to 11 Mile Rd	0.154	SB	3,407	2,922	7	0	0.002
11 Mile Rd SB Entrance Ramp	0.113	SB	8,738	2,922	11	0	0.004
SB Exit Ramp to I-696	0.151	SB	36,197	2,922	37	5	0.013
I-696 SB Entrance Ramp	0.099	SB	33,939	2,922	9	2	0.003
SB Exit Ramp to 9 Mile Rd	0.141	SB	6,662	2,922	24	3	0.008
9 Mile Rd SB Entrance Ramp	0.157	SB	4,591	2,922	2	0	0.001
SB Exit Ramp to 8 Mile Rd	0.176	SB	7,407	2,922	13	2	0.004
8 Mile Rd SB Entrance Ramp	0.194	SB	10,974	2,922	9	1	0.003
All Ramps	**11.049**	**-**	**10,419**	**128,568**	**709**	**84**	**0.006**