

JOINT TRANSPORTATION RESEARCH PROGRAM

INDIANA DEPARTMENT OF TRANSPORTATION
AND PURDUE UNIVERSITY



Case Studies Documenting Lessons Learned and Identifying Opportunities for Maintenance of Traffic (MOT) Improvements



**Myles W. Overall, Justin Mukai, Rahul Suryakant Sakhare,
Jairaj Desai, Deborah Horton, and Darcy M. Bullock**

RECOMMENDED CITATION

Overall, M. W., Mukai, J., Sakhare, R. S., Desai, J., Horton, D., & Bullock, D. M. (2025). *Case studies documenting lessons learned and identifying opportunities for maintenance of traffic (MOT) improvements* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2025/29). West Lafayette, IN: Purdue University. <https://doi.org/10.5703/1288284318578>

AUTHORS

Myles W. Overall, EIT

Graduate Research Assistant
Lyles School of Civil and Construction Engineering
Purdue University
moverall@purdue.edu
Corresponding Author

Justin Mukai, EIT

Graduate Research Assistant
Lyles School of Civil and Construction Engineering
Purdue University

Rahul Suryakant Sakhare, PhD

JTRP Transportation Research Engineer
Lyles School of Civil and Construction Engineering
Purdue University

Jairaj Desai, PhD

JTRP Transportation Research Engineer
Lyles School of Civil and Construction Engineering
Purdue University

Deborah Horton

JTRP Managing Director
Purdue University

Darcy M. Bullock, PhD, PE

Lyles Family Professor of Civil Engineering
JTRP Director
Lyles School of Civil and Construction Engineering
Purdue University

ACKNOWLEDGMENTS

Anonymized connected truck data used in this study was provisioned by Omnitrac. Anonymized connected vehicle data used in this study was provided by Streetlight. Dash camera images from commercial trucks used in this study were provided by Vizion. The feasibility study performed were performed ChatGPT o4-mini and Google Gemini 2.5 Flash. The contents of this study reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein and do not necessarily reflect the official views or policies of the sponsoring organizations. These contents do not constitute a standard, specification, or regulation. This work was supported by the Joint Transportation Research Program (JTRP) administered by the Indiana Department of Transportation (INDOT) and Purdue University.

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TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FHWA/IN/JTRP-2025/29	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Case studies documenting lessons learned and identifying opportunities for maintenance of traffic (MOT) improvements		5. Report Date October 28, 2025	
		6. Performing Organization Code	
7. Author(s) Myles W. Overall, EIT (https://orcid.org/0000-0002-3223-8502) Justin Mukai, EIT (https://orcid.org/0000-0003-0044-3816) Rahul Suryakant Sakhare, PhD (https://orcid.org/0000-0001-7843-5707) Jairaj Desai, PhD (https://orcid.org/0000-0003-2885-203X) Deborah Horton (https://orcid.org/0000-0003-3293-8856) Darcy M. Bullock, PhD, PE (https://orcid.org/0000-0002-7365-1918)		8. Performing Organization Report No. FHWA/IN/JTRP-2025/29	
		9. Performing Organization Name and Address Joint Transportation Research Program Hall for Discovery and Learning Research (DLR), Suite 204 207 S. Martin Jischke Drive West Lafayette, IN 47907	
11. Contract or Grant No. SPR-4854			
12. Sponsoring Agency Name and Address Indiana Department of Transportation (SPR) State Office Building 100 North Senate Avenue Indianapolis, IN 46204		13. Type of Report and Period Covered Final Report	
		14. Sponsoring Agency Code	
15. Supplementary Notes Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.			
16. Abstract Over the past 18 months, the team has performed several dozen after-action reviews of interstate work zones and the associated maintenance of traffic (MOT). These after-action reports generally contain the following information: Date, location, visual images, connected vehicle summary graphics, qualitative discussion of activity, and in some cases press releases or media posts. In general, these themes emerged: <ol style="list-style-type: none"> 1. MOT plans in some cases do not accurately capture the geometry constraints placed by bridges, guardrail and or barrier wall. It is important that design reviews place careful focus on ensuring lane widths, shoulders, and shoulder treatments fit across the entire cross section of each phase or requests for design exceptions be initiated. In some cases, performing some type of LiDAR survey prior to design may assist MOT designers in effectively capturing more accurate location and dimensions of existing geometrics, particularly edge of pavement, edge of bridge, guardrails, and embankments. 2. When lane shifts are initiated, the designers should examine the path of the vehicle at both the start and end of the transition. In some cases, the end of the transition occurs quite close to either a guardrail or narrow section of pavement. In some cases, either gentler transitions or additional horizontal clearance should be considered. 3. There is relatively little dialog between the temporary traffic control contractors and designers on what are the best practices and requirements for implementing a change in MOT. 4. To sustain this engagement between designers, and MOT contractors, it is recommended that selected projects include MOT review with design engineers, and contractor as part of the close out process to document lessons learned. 5. Rolling slows downs have a role in MOT, but there appears to be inconsistent use of rolling slowdowns for short term closures. It is recommended that requirements for rolling slowdowns be identified in the MOT plans. If contractors are required to use rolling slowdowns not documented in MOT plans, they should be required to obtain approval from the Indiana Department of Transportation and notify the Traffic Management Center. 6. Barrier walls are an important tool for MOT. However, their set up can have significant impact on traffic capacity and create queues. Project plans should define days/time periods these are permitted to be installed and/or removed. 			
17. Key Words traffic, work zones, connected vehicle, MOT, dash cameras, inspection		18. Distribution Statement No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 25, including appendices	22. Price

EXECUTIVE SUMMARY

From July 2023 to July 2025, the team has performed several dozen after-action reviews of interstate work zones and the associated maintenance of traffic (MOT). These after-action reports generally contain the following information: Date, location, visual images, connected vehicle summary graphics, qualitative discussion of activity, and in some cases press releases or media posts. This report highlights a cross section of 13 after-action reports. In general, these themes emerged:

1. MOT plans in some cases do not accurately capture the geometry constraints placed by bridges, guardrail, and/or barrier wall. It is important that design reviews place careful focus on ensuring lane widths, shoulders, and shoulder treatments fit across the entire cross section of each phase or requests for design exceptions be initiated. In some cases, performing some type of LiDAR survey prior to design may assist MOT designers in effectively capturing more accurate location and dimensions of existing geometrics, particularly edge of pavement, edge of bridge, guardrails, and embankments.
2. When lane shifts are initiated, the designers should examine the path of the vehicle at both the start and end of the transition. In some cases, the end of the transition occurs quite close to either a guardrail or narrow section of pavement. In some cases, either gentler transitions or additional horizontal clearance should be considered.
3. There is relatively little dialog between the temporary traffic control contractors and designers on what are the best practices and requirements for implementing a change in MOT. We recommend a near-term approach of incorporating some of the existing after-actions (I-65: Narrow shoulder, Lane shift taper length, Missing marking and inconsistent markings, and I-65 Variable work zone speed limit trailer in close proximity to speed limit sign) into one or more of the Indiana Department of Transportation (INDOT) Safety Summits to start that dialog.
4. To sustain this engagement between designers and MOT contractors, it is recommended that selected projects include MOT review with design engineers and contractors as part of the close-out process to document lessons learned.
5. Rolling slowdowns have a role in MOT, but there appears to be inconsistent use of rolling slowdowns for short-term closures. It is recommended that requirements for rolling slowdowns be identified in the MOT plans. If contractors are required to use rolling slowdowns not documented in MOT plans, they should be required to obtain approval from INDOT and notify the Traffic Management Center.
6. Barrier walls are an important tool for MOT. However, their set up can have significant impact on traffic capacity and create queues. Project plans should define days/time periods these are permitted to be installed and/or removed.

CONTENTS

1. INTRODUCTION	8
1.1 Background	8
1.2 Project Scope.	8
1.3 Inspection Procedures	8
1.3.1 Agency Operated Camcorders and Dash Cameras	8
1.3.2 Commercial Dash Camera Technology.	8
1.3.3 Coverage of Commercial Dash Cameras	8
1.3.4 Near-Term Dash Camera Inspection Workflow for Agencies and Data Costs	9
2. CASE STUDIES	11
2.1 Case Study I: Material Transfer Lane Incursion	11
2.2 Case Study II: Shoulder & Lane Geometry/Pavement Markings	12
2.2.1 Lane Shift Taper Length	12
2.2.2 Temporary Pavement Marking Consistency	12
2.2.3 Limited Distance from Pavement Edge Line to Adjacent Unpaved Shoulder	12
2.3 Case Study III: Speed Limits and Signing	13
2.3.1 Variable Work Zone Speed Limit Trailer in Close Proximity to Speed Limit Sign	13
2.3.2 Work Zone Speed Limit Signage Inconsistency	13
2.3.3 Misspelt and Incorrect PCMS Message.	14
2.4 Case Study IV: Pavement Geometry and Width Constraints	14
2.5 Case Study V: Mobile Operations Protection	14
2.6 Case Study VI: Rolling Slowdowns	15
2.7 Case Study VII: Queue Warning Management	16
2.8 Case Study VIII: Short-Term Maintenance Activities	18
2.8.1 Spraying Operation	18
2.8.2 Moving Maintenance	18
2.9 Case Study IX: Barrier Wall Installation.	18
3. OPPORTUNITIES TO IMPROVE EFFICIENCY OF INSPECTION WITH AI AND COMMERCIAL DASH CAMERAS.	20
4. CONCLUSIONS	20
4.1 Candidate Opportunities to Address	20
REFERENCES	22
APPENDICES	23
Appendix A. List of Acronyms	23

LIST OF TABLES

Table 1.1 Example Case Studies of Work Zone Drive Throughs.	10
Table 2.1 After-Actions Case Studies Included in Report.	11
Table 3.1 Summary of Images Submitted to ChatGPT o4-mini and Gemini 2.5 Flash.	20
Table 3.2 Summary of AI Submission Results.	20

LIST OF FIGURES

Figure 1.1	Dash Camera Images Along I-69 in Indiana Verifying MUTCD Work Zone Design.	9
Figure 1.2	MUTCD Typical Application 44: Work in the Vicinity of an Entrance Ramp.	9
Figure 2.1	Traffic Speed Heatmap for a Section of I-65 in Indiana From MM 230 to MM 245 on Wednesday, May 15, 2024 and Thursday, May 16, 2024.	11
Figure 2.2	Dash Camera Image Showing a Semitruck Driving on the Shoulder Through a work Zone During a Material Transfer Operation.	12
Figure 2.3	A Double Lane Shift Inside of a Work Zone.	12
Figure 2.4	A Damaged Guardrail.	12
Figure 2.5	Dash Camera Image Showing Right No Right Edge Line Pavement Markings.	12
Figure 2.6	Image Showing Inconsistent Right Edge Line Pavement Markings and Inconsistent Lane Widths.	13
Figure 2.7	Dash Camera Images Along Northbound I-65.	13
Figure 2.8	ITS Camera Image Along I-65 at MM 3.7 Showing a Variable Work Zone Speed Limit Trailer in Close Proximity to a Static Speed Limit Sign.	13
Figure 2.9	Dash Camera Image Along Southbound I-69 Near Mile Marker 273 on August 12, 2024 Showing Different Speed Limit Signage at the Same Location.	13
Figure 2.10	Several Images of a Work Zone With a PCMS Sign Showing “ALL LINES OPEN.”	14
Figure 2.11	Dash Camera Images Showing a Recently Constructed Shoulder With No Pavement Markings and Narrow Lanes.	14
Figure 2.12	Traffic Speed Heatmap for a Section of I-69 in Indiana From MM 270 to MM 290 on Wednesday, October 16, 2024.	15
Figure 2.13	ITS Camera Images Showing a Moving Work Convoy Putting Down Pavement Markings.	15
Figure 2.14	Traffic speed Heatmap for a Section of I-65 in Indiana From MM 70 to MM 90 on Monday, February 3, 2025 and Tuesday, February 4, 2025.	16
Figure 2.15	ITS Camera Image Along I-65 Near Mile Marker 86.5 Showing a DMS Sign Being Installed.	16
Figure 2.16	A Social Media Post Showing an Incident Clearing Between MM 86 and MM 87.	16
Figure 2.17	Traffic Speed Heatmap for a Section of I-65 in Indiana From MM 225 to MM 245 on Thursday, October 10, 2024 and Friday, October 11, 2024.	17
Figure 2.18	Dash Camera Image Showing a Semitruck Approaching a stopped Queue With No Advanced Warning.	17
Figure 2.19	Traffic Speed Heatmap for a Section of I-70 in Indiana from MM 30 to MM 70 on Friday, June 21, 2024.	18
Figure 2.20	ITS Camera Image Showing a Moving Work Convoying in the Left Lane of I-70.	18
Figure 2.21	Traffic Speed Heatmap for a Section of I-65 in Indiana From MM 140 to MM 160 on Tuesday, October 22, 2024.	19
Figure 2.22	Dash Camera Image Showing a Semitruck Traveling by a Work Convoy on the Outside Shoulder.	19
Figure 2.23	ITS Camera Images Along I-65 Near MM 256.3 on June 20, 2025 Showing the Installation of Temporary Concrete Barriers Next to Live Traffic.	19
Figure 3.1	Images and AI Response From Each Model for the Five Images Where the Authors Disagreed With the AI Model. The Response the Authors Disagreed With is Shown as Red Text.	21

1. INTRODUCTION

The interstate highway system is now in an era of maintenance and reconstruction of facilities that have reached their design life. Many of these facilities are at or near capacity, which makes it challenging for construction projects to temporarily reduce the number of lanes. As a result, designers must invest considerable effort to develop effective maintenance of traffic (MOT) practices that provide a safe worksite and provide reasonable mobility.

Although this report devotes considerable effort to detailing after-action review of recently completed MOT deployments and identifying opportunities for improvement, for this report to have significant impact on future projects, it is important to develop a series of outreach activities that improve the engagement between design engineers and MOT contractors to ensure MOT designs can be deployed in a cost-effective manner to provide safe and efficient mobility through work zones.

1.1 Background

Work zone mobility and safety is a national problem. In 2023, there were more than 100,000 work zone crashes across the United States (National Work Zone Safety Information Clearinghouse, 2025). Agencies devote considerable time and effort to carefully designing work zone geometries, markings and signs to ensure high quality MOT. However, work zones are extremely complex due to the large numbers of stakeholders ranging from initial design engineers, prime contractors, and subcontractors.

In general, challenges in work zone MOT emerge in three areas:

1. *Discrepancies between design engineers' understanding of existing geometry and actual geometry available:* Areas adjacent to bridges and guardrail placement can be areas where precision down to the inch are important. Some of these discrepancies are often not identified until construction has begun.
2. *Exception to design policies regarding lane width and shoulders:* As with any design exception, it is critical to ensure proper documentation is in place to support the design exception.
3. *Discrepancies between the MOT design plans and the constructed MOT:* It is important to have effective inspection in place to ensure the designed MOT is implemented, or in case when it is not implemented according to design plans, there is appropriate documentation on deviations from MOT designs.

1.2 Project Scope

This project focused on performing a detailed review of selected interstate projects to assemble a portfolio of MOT practices for subsequent after-action review and to inform future practices. The following sections review inspection practices, information that can be extracted, and a library of case studies.

1.3 Inspection Procedures

Inspection practices have evolved considerably in recent years. The following section provides a brief overview of those techniques and transitions to explaining emerging crowd sourced dash cameras.

1.3.1 Agency Operated Camcorders and Dash Cameras

Perhaps the most common inspection technique for transportation agencies is to drive through a work zone to perform inspections. In earlier years, this was often done in two-person teams with one driving and one taking notes. More recently, many agencies have transitioned to using consumer electronic devices, such as GoPro cameras, that can geotag latitude and longitude on a digital image every 0.5–1.0 s. This has the ability of providing precise location information if further follow up is required. However, this still requires significant travel to and from job sites and does not scale well.

1.3.2 Commercial Dash Camera Technology

Many private motorists and public agencies have begun including dash cameras in their vehicles for risk management and loss protection. The commercial trucking industry has been particularly aggressive at integrating dash cameras across their fleets, and there are now a number of dash camera providers for the commercial truck industry. Some of those providers have business models with consented user agreements that allow truck images to be shared with external stakeholders, such as public agencies. While commercial truck dash cameras have been used to verify roadway and traffic conditions (Mathew et al., 2025; Sakhare, Desai, Mathew, & Bullock, 2024a), the use of dash cameras for work zone related tasks is an emerging opportunity (Overall et al., 2026).

1.3.3 Coverage of Commercial Dash Cameras

Past studies have reported some commercial truck dash camera providers have 30,000–60,000 trucks with images that may be downloaded at approximately 1-s intervals on demand (Sakhare, Desai, Mathew, & Bullock, 2024b). That study reported that virtually all sections of Indiana interstates are covered by imagery at least a few times a day during each day of the week, with some modest decrease in coverage on weekends when there are fewer commercial trucks on the interstates. Some of the busier corridors, such as Interstate 65 (I-65) in Indiana, frequently have four or more trucks per hour that can provide dash camera imagery at 1-s intervals. Figure 1.1 shows example imagery from a truck on southbound Interstate 69 (I-69) on August 12, 2024. Using linear referencing techniques, each commercial truck dash camera image is associated with an interstate route, direction of travel, and a mile marker location along the route (Sakhare, Desai, Mathew, & Bullock, 2024b).

Metadata associated with the image provide valuable context for the images. At the top of the image shown in Figure 1.1a, the following metadata attributes are visibly encoded on the image overlay:

- Internal Purdue Identifier: PU929770
- State: IN
- Route: I-69S
- Mile Marker (MM): 273.3



(a) Arrow Board at Merge Point



(b) "LANE ENDS MERGE LEFT" Sign 1,000 ft in Advance of Merge Point

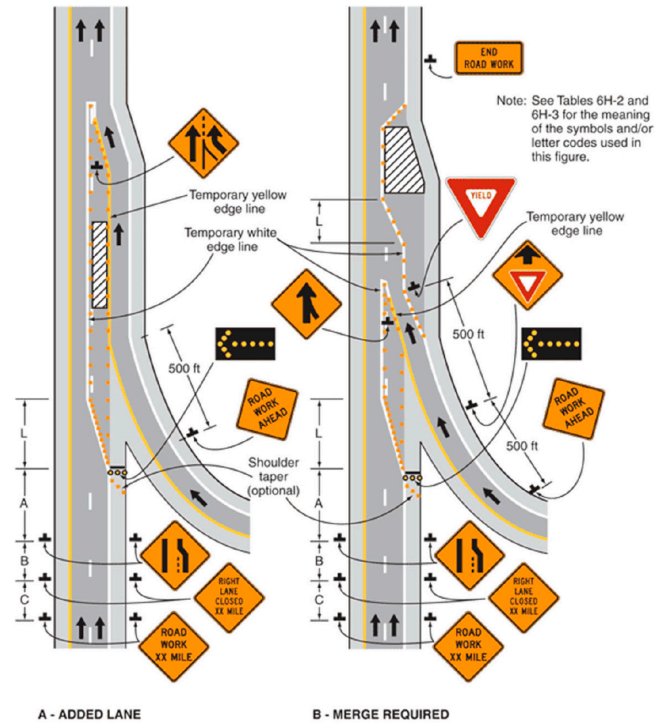


(c) "RIGHT LANE CLOSED AHEAD" Sign 2,500 ft in Advance of Merge Point

Figure 1.1 Dash Camera Images Along I-69 in Indiana Verifying MUTCD Work Zone Design.

- Local Date and Time: 2024-08-12, 17:16:15
- Speed: 22 MPH

Comparing Figure 1.1b and Figure 1.1c, the MM changes to 273.5 and 273.7, the time to 17:15:12 and 17:14:42, and the speed to 16 and 27 mph, respectively. The visible side mirrors in the lower left and right corner also provide evidence that these images were captured from a commercial truck. These dash camera images from Figure 1.1 can be used to identify Manual on Uniform Traffic Control Devices (MUTCD) traffic control devices such as signs and markings. A subject matter expert can then cross-reference the images with standard agency practices. Figure 1.2 is adapted from the Federal Highway Administration's (2023) MUTCD to illustrate the practices transportation agencies typically follow for sign placements near an interchange entrance ramp. In this simple example, one can see the arrow board in Figure 1.1a, two orange W4-1 signs in Figure 1.1b, and two orange W20-5 signs in Figure 1.1c align with the configuration recommended in Figure 1.2.



Typical Application 44

Figure 1.2 MUTCD Typical Application 44: Work in the Vicinity of an Entrance Ramp.

1.3.4 Near-Term Dash Camera Inspection Workflow for Agencies and Data Costs

This technology is at the point where imagery from relatively large segments of roadways can be downloaded on a weekly basis. The current download capacity of Purdue is to retrieve approximately 10,000 images per week from commercial dash camera providers. That imagery can cover approximately 400 mi of interstate. Early efforts to scale this indicate approximately 400 mi of interstate can be monitored per week with a data service cost on the order of \$3,400 per month.

In the near term, this is a very cost-effective replacement for traditional "windshield" inspection where an agency or contractor drives the work zone. In Indiana, a work zone of interest can be automatically downloaded on one day and a quick frame by frame "virtual" drive to examine key elements and determine if they have changed can be done the following day in approximately an hour of combined machine and manual effort. Table 1.1 provides examples of the types of videos that can be automatically assembled and quickly viewed. This is particularly valuable in tracking progress. Entries of I, J, and K illustrate videos from sequential time periods of the same zone.

The following section discusses a series of case studies. Several examples from outside of Indiana have been incorporated to demonstrate how well these commercial truck dash camera inspection techniques scale nationally.

TABLE 1.1
Example Case Studies of Work Zone Drive Throughs.













Case	Date	Interstate & MM Range	Short Description	YouTube Video Link	QR Code
A	06/03/2024	I65S MM209-201	Single Lane Overnight Closure	Link	
B	09/26/2024	I65N MM158-168	Right Shoulder Spraying Operation (0:41 in video)	Link	
C	06/19/2024	I70W MM45-65	Left Shoulder Spraying Operation (0:37 in video)	Link	
D	05/07/2024	I70W MM1-0	Single Lane Closure, Queuing from Illinois into Indiana	Link	
E	05/15/2024	I65S MM239-236	Single Lane Overnight Closure	Link	
F	10/07/2024	I70E MM134-146	Single Lane Closure Daytime Patching	Link	
G	08/12/2024	I69S MM275-270	Single Lane Closure Daytime Pavement Repair	Link	
H	07/10/2025	I74W MM40-30	Single Lane Closure for Resurfacing	Link	
I	10/11/2024	I65N MM230-240	Overnight Bifurcated Crossover	Link	
J	06/25/2025	I65N MM234-239	Double Lane Shift	Link	
K	07/12/2025	I65N MM234-239	Double Lane Shift	Link	
L	07/12/2025	I65S MM240-234	Bifurcated Crossover	Link	

TABLE 2.1
After-Actions Case Studies Included in Report.

Case Study Title	Location	Date	Opportunities for Review	
			Geometry	Communication & Coordination
Material Transfer Lane Incursion	I-65S MM235-239	05/15/2024	X	
Shoulder & Lane Geometry/Pavement Markings	I-65S MM235-239	04/11/2025	X	
Variable Work Zone Speed Limit Trailer in Proximity to Speed Limit Sign	I-65 MM3.7	04/17/2025		X
Work Zone Speed Limit Signage Inconsistency	I-69 MM273	08/12/2024		X
Misspelt and Incorrect PCMS Message	I-265 MM7.8	03/05/2025		X
Pavement Geometry and Width Constraints	I-65 MM207	07/29/2024	X	
Mobile Operations Protection	I-69 MM273	10/16/2024		X
Rolling Slowdowns	I-65 MM86	02/03/2024		X
Queue Warning Management	I-65 MM232	10/10/2024		X
Moving Spraying Operation	I-70 MM55	06/21/2024	X	
Moving Maintenance Operation	I-65 MM153	10/22/2024	X	
Barrier Wall Installation	I-65 MM256	06/25/2025		X

2. CASE STUDIES

Select after-action case studies are discussed in this section that illustrate several issue types including geometry, MOT design, and Communication and Coordination. Table 2.1 highlights the case studies with the title, location, and issue type. The selection of case studies is quite diverse and looks at opportunities for review regarding geometry and communication and coordination. The case studies use several connected vehicle data sources that previous studies have highlighted in being an effective use to measure freeway conditions including secondary

crashes, shockwaves, and mobility (Desai et al., 2021; Desai et al., 2022; Mekker et al., 2020; Sakhare, 2023; Sakhare, Desai, et al., 2023; Sakhare et al., 2021, 2022; Sakhare, Desai, Mathew, McGregor, et al., 2024; Sakhare, Desai, Saldivar-Carranza, & Bullock, 2024; Sakhare, Li, et al., 2023).

2.1 Case Study I: Material Transfer Lane Incursion

This case study shows an overnight work zone involving a single right lane closure along southbound I-65 between MM 239 and 235. Figure 2.1 shows a traffic speed heatmap for the

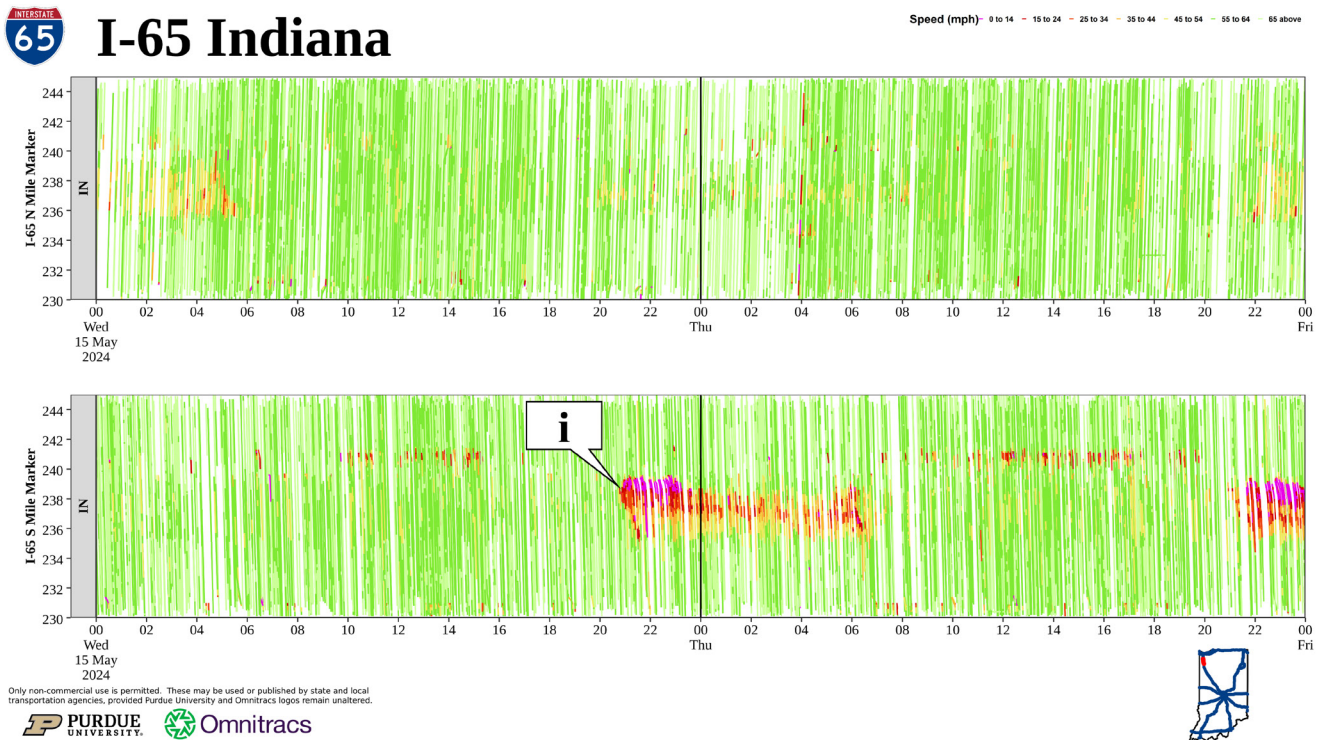


Figure 2.1 Traffic Speed Heatmap for a Section of I-65 in Indiana From MM 230 to MM 245 on Wednesday, May 15, 2024 and Thursday, May 16, 2024.



Figure 2.2 Dash Camera Image Showing a Semitruck Driving on the Shoulder Through a Work Zone During a Material Transfer Operation.

section of I-65 with Callout i showing the congestion from the queuing due to the single lane closure. The specific work involved a material transfer vehicle needing to be on the travel lane side of the temporary concrete barrier to transfer the material over the wall (Figure 2.2). Due to this, the vehicle incurred on the single travel lane (Callout ii) for the southbound direction requiring passing vehicles to utilize the shoulder to traverse around the ongoing work (Callout i). Due to the limit width of the inside shoulder, the potential for run-off-the-road crashes can increase, especially for semitrucks.

There is opportunity to discuss with MOT designers on making sure temporary lane widths are accounted for when designing and planning for these types of overnight work operations.

2.2 Case Study II: Shoulder & Lane Geometry/Pavement Markings

2.2.1 Lane Shift Taper Length

This case study shows a work zone where a double lane shift to the right is present at the start of the work area. Figure 2.3 shows a potential issue where the trajectory of the lane shift leads the vehicles in the right lane to the edge of the pavement.

Figure 2.3 shows a damaged guardrail and tire tracks in the aggregate next to the roadway, likely due to a run-off-the-road crash.



Figure 2.3 A Double Lane Shift Inside of a Work Zone.



Figure 2.4 A Damaged Guardrail.

The opportunity here is to discuss with MOT designers to increase the length of the taper and allow for a longer taper so that there are fewer sharp curves, especially when a shoulder is narrow with little room for correction.

2.2.2 Temporary Pavement Marking Consistency

This case study shows a work zone along I-65 where some of the right edge line pavement markings line are missing, as shown in Figure 2.5. Furthermore, Figure 2.6 shows inconsistent pavement markings for the right edge line, which also varies the available lane widths. With the shoulder width already being narrow, the need to have pavement markings and for them to be consistent along with consistent lane widths is paramount.

The opportunity here is to discuss with contractors and inspectors to make sure that consistency is followed throughout work zones and that lane widths need to be consistent, markings need to not only be in place but that they are consistent.

2.2.3 Limited Distance from Pavement Edge Line to Adjacent Unpaved Shoulder

With the close proximity of the edge line to the shoulder along this section of I-65 through the work zone, there were a substantial number of vehicles, particularly trucks, with tires



Figure 2.5 Dash Camera Image Showing Right No Right Edge Line Pavement Markings.



Figure 2.6 Image Showing Inconsistent Right Edge Line Pavement Markings and Inconsistent Lane Widths.



(a)



(b)

Figure 2.7 Dash Camera Images Along Northbound I-65.

running on the unpaved shoulder, as shown in Figure 2.7 with Callout i. This required further unplanned MOT for shoulder maintenance.

The opportunity in this case study is to work with MOT designers to make sure that the minimum shoulder width is met for not only the paved section of the roadway but for the unpaved section, as well.

2.3 Case Study III: Speed Limits and Signing

2.3.1 Variable Work Zone Speed Limit Trailer in Close Proximity to Speed Limit Sign

This case study shows a single lane closure along northbound I-65 on April 17, 2025, near MM 3.7. Figure 2.8 shows



Figure 2.8 ITS Camera Image Along I-65 at MM 3.7 Showing a Variable Work Zone Speed Limit Trailer in Close Proximity to a Static Speed Limit Sign.

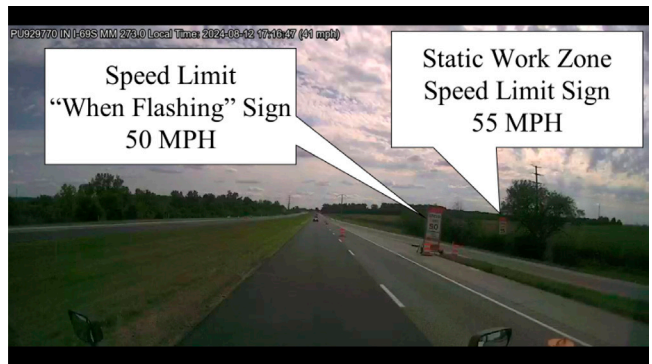


Figure 2.9 Dash Camera Image Along Southbound I-69 Near Mile Marker 273 on August 12, 2024 Showing Different Speed Limit Signage at the Same Location.

an intelligent transportation system (ITS) camera image where a static speed limit sign is approximately 50 ft upstream of a temporary work zone “When Flashing” speed limit trailer. While this is within the standard of the MUTCD (FHWA, 2023) and the Indiana Manual on Uniform Traffic Control Devices (IMUTCD; INDOT, 2025), this setup can be confusing to motorists if it is within quick succession, like shown.

The opportunity here is a discussion with MOT designers to have larger distance between the speed limits and cover the static sign if necessary. While the setup itself may be correct, it can be confusing to motorists having different speed limits next to each other. Digital speed limit trailers may be a better option to use here to avoid multiple speed limit assemblies.

2.3.2 Work Zone Speed Limit Signage Inconsistency

This case study shows a single lane closure along southbound I-69 near MM 273 on August 12, 2024. Figure 2.9 shows a dash camera image. Specifically, the entrance ramp at this location has a static work zone speed limit sign displaying “55 MPH” while also having a work zone speed limit trailer that displays “50 MPH” with the “When Flashing” plaque below.

By Indiana Code, the intermittent setup of “When Flashing” requires workers to present. However, if workers are present,



(a)



(b)

Figure 2.10 Several Images of a Work Zone With a PCMS Sign Showing “ALL LINES OPEN.”

then that would also mean they are exposed with no positive protection meaning a 45 mph speed limit should be used instead.

The opportunity here is to discuss with MOT designers to make sure the correct speed limits are being used to further protect workers if no positive protection is available. While the setup itself may be correct, it can be confusing to motorists having different speed limits next to each other. Digital speed limit trailers may be a better option to use here to avoid multiple speed limit assemblies. Furthermore, the temporary sign assemblies should be moved further downstream of the interchange, similar to permanent signage.

2.3.3 Misspelt and Incorrect PCMS Message

This case study shows a temporary work zone for shoulder work, requiring intermittent right lane closures along a two-lane section of Interstate 265 (I-265). The potential issues include the misspelt portable changeable message (PCMS) saying “ALL LINES OPEN” instead of “ALL LANES OPEN,” as shown in Figure 2.10a. Furthermore, Figure 2.10a and Figure 2.10b demonstrate incorrectly displayed messages as the truck-mounted attenuator (TMA) truck is in the right lane, therefore closing the lane from travel. The message should then be displaying “RIGHT LANE CLOSED.”

The opportunity here is to discuss with MOT contractors to make sure that, not only are the PCMS messages spelt correctly, but to also make sure the correct message is being displayed.



(a)



(b)

Figure 2.11 Dash Camera Images Showing a Recently Constructed Shoulder With No Pavement Markings and Narrow Lanes.

If the right lane is closed but the PCMS is displaying that all lanes are open, the potential for further incidents may arise.

2.4 Case Study IV: Pavement Geometry and Width Constraints

This case study shows a temporary overnight work zone with a single lane closure. Figure 2.11 shows two dash camera images along the work zone. With the single travel lane being recently reconstructed, there are no pavement markings placed yet and the lane widths are narrow due to the ongoing construction. The potential for run-off-the-road crashes can increase in situations like this due to larger vehicles needing to maintain a stricter lane compliance for a longer distance.

The opportunity is to discuss with MOT designers and contractors to make sure that minimum lane widths are maintained as well as shoulder widths. The ability to give drivers more opportunity to correct can reduce run-off-the-road crashes in these types of work zones.

2.5 Case Study V: Mobile Operations Protection

This case study shows a moving work crew putting down centerline pavement markings during the daytime along I-69. Figure 2.12 shows a traffic speed heatmap with Callout i showing the moving congestion in the southbound direction. In Figure 2.13, both images show that traffic is being pushed

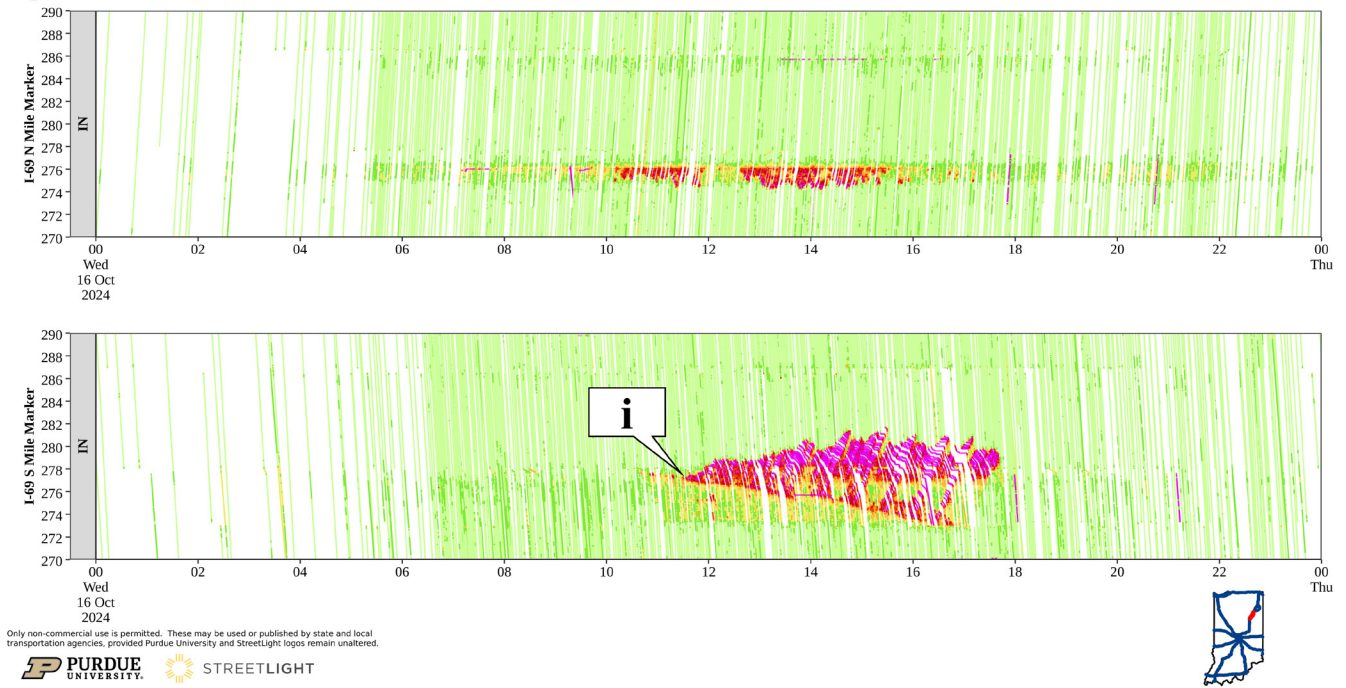
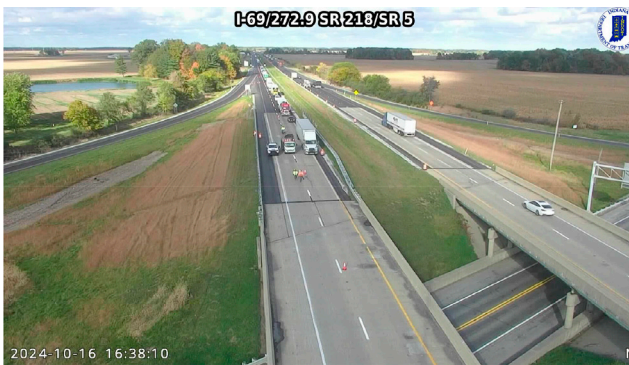
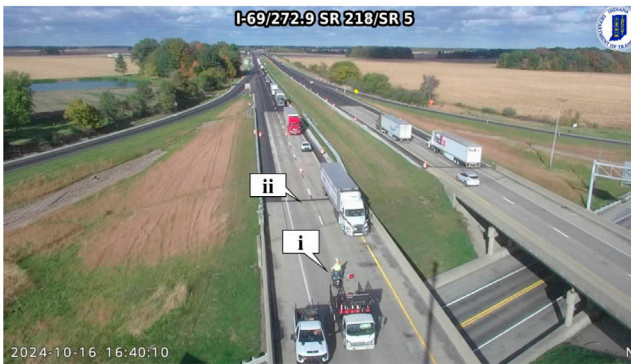


Figure 2.12 Traffic Speed Heatmap for a Section of I-69 in Indiana From MM 270 to MM 290 on Wednesday, October 16, 2024.



(a)



(b)

Figure 2.13 ITS Camera Images Showing a Moving Work Convoy Putting Down Pavement Markings.

to the inside shoulder, requiring drivers to be within a few feet of the guardrail and barrier wall on this bridge. Callout i in Figure 2.13b shows the buggy applying the marking, and Callout ii shows that there is no TMA truck in the empty lane to protect the work party.

Pavement markings are not required to be placed during the day and sometimes can be preferred to be done at night due to lower volumes. Regardless, if pavement markings are being placed, there should be protection for the operators of the machines that are placing these markings.

The opportunity from this case study is to discuss with contractors about making sure the operators of the buggies have some type of protection, preferably a TMA truck. Furthermore, the contractors for these projects should have pay items to not only allow for this but to also require it.

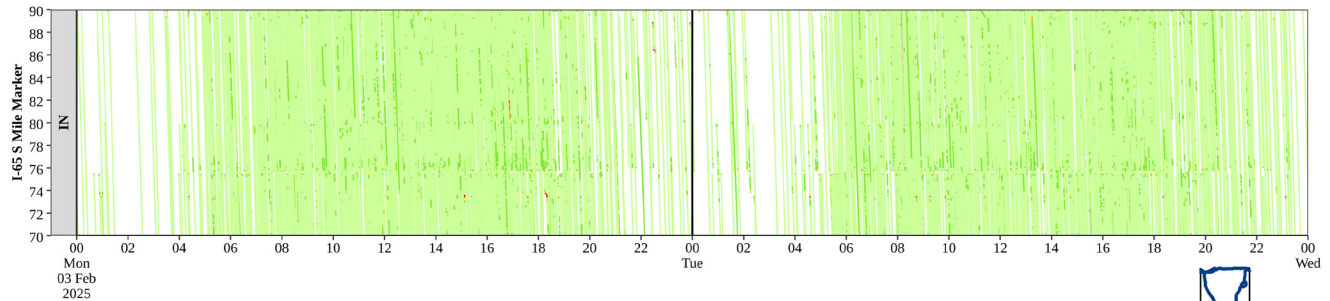
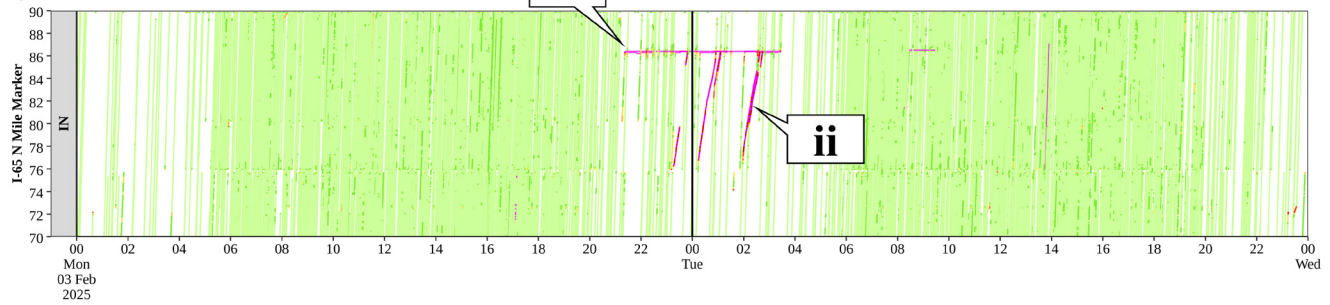
2.6 Case Study VI: Rolling Slowdowns

This case study shows a heatmap along I-65 with an overnight work operation to install a dynamic message sign (DMS). In Figure 2.14, the pink horizontal line (Callout i) shows a connected vehicle that is stopped near mile marker 86 in the northbound direction which is likely a work vehicle involved with the installation of the DMS. Callout ii shows one of three vertically slanted lines showing a slow-moving vehicle approaching MM 86, three separate times. This particular case was three rolling slowdowns to install a DMS (Figure 2.15) which requires breaks in the traffic to allow for



I-65 Indiana

Speed (mph) 0 to 14 15 to 24 25 to 34 35 to 44 45 to 54 55 to 64 65 above



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Figure 2.14 Traffic Speed Heatmap for a Section of I-65 in Indiana From MM 70 to MM 90 on Monday, February 3, 2025 and Tuesday, February 4, 2025.



Figure 2.15 ITS Camera Image Along I-65 Near Mile Marker 86.5 Showing a DMS Sign Being Installed.

the sign to be placed overhead of the lanes. Figure 2.16 shows a social media post that states that an incident has cleared around 2:39 a.m. but does not specify what it was. In this situation, the details do not appear to have been communicated

to the Indiana Department of Transportation (INDOT) traffic management center (TMC).

The opportunity in this case study is to discuss with MOT designers, contractors, state department of transportation (DOT) officials, and Indiana State Police (ISP) to make sure there is clear communication on when rolling slowdowns are being performed and for how long. TMC operators can alert motorists through DMS messaging as well as PCMS setups, if needed.

2.7 Case Study VII: Queue Warning Management

This case study shows a heatmap along I-65 with an overnight work operation. During the daytime, the northbound direction has a bifurcated crossover for one of the lanes meaning that one lane of northbound traffic crosses over the median and runs on the southbound side of I-65. The heatmap in Figure 2.17 shows the bifurcated section between MM 236 and MM 238 by Callout i.

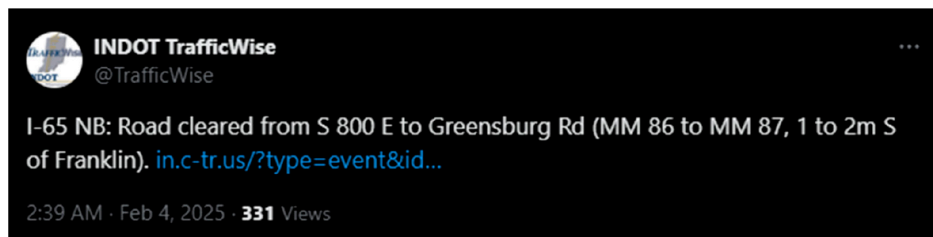
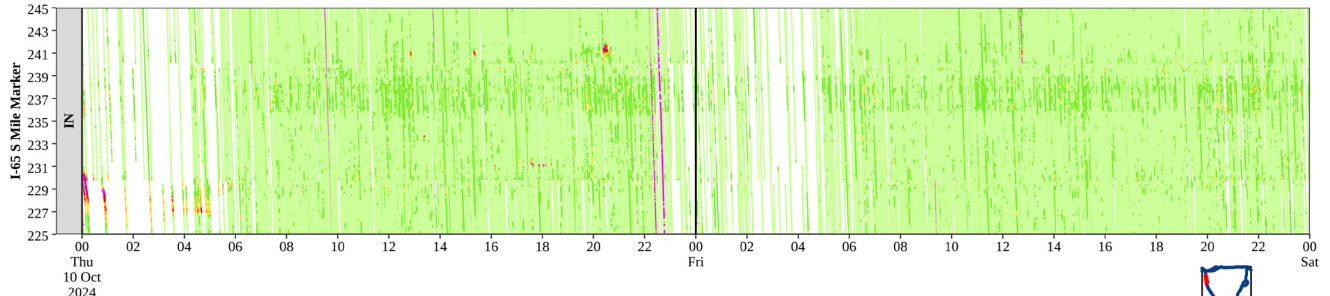
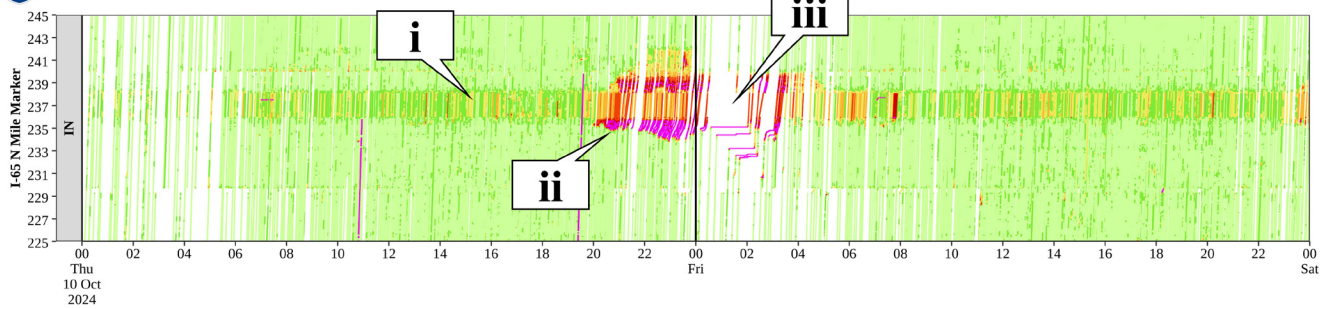


Figure 2.16 A Social Media Post Showing an Incident Clearing Between MM 86 and MM 87.



I-65 Indiana

Speed (mph) 0 to 14 15 to 24 25 to 34 35 to 44 45 to 54 55 to 64 65 above



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Figure 2.17 Traffic Speed Heatmap for a Section of I-65 in Indiana From MM 225 to MM 245 on Thursday, October 10, 2024 and Friday, October 11, 2024.



Figure 2.18 Dash Camera Image Showing a Semitruck Approaching a Stopped Queue With No Advanced Warning.

Callout ii is the queuing from the start of the right lane closure, with all the traffic using the bifurcated crossover lane. Callout iii shows no traffic in the northbound direction of the nonbifurcated side due to the full closure of that lane. Figure 2.18 shows a dash camera image of a semitruck approaching the stopped queue with no advanced warning. This can potentially lead to

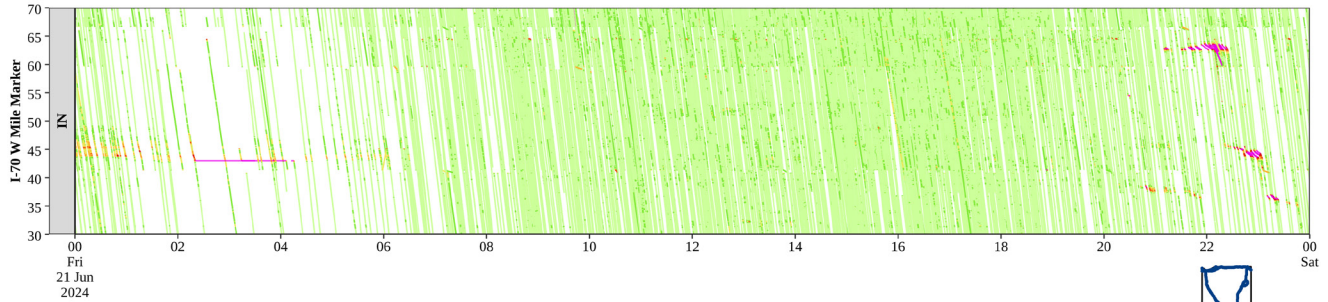
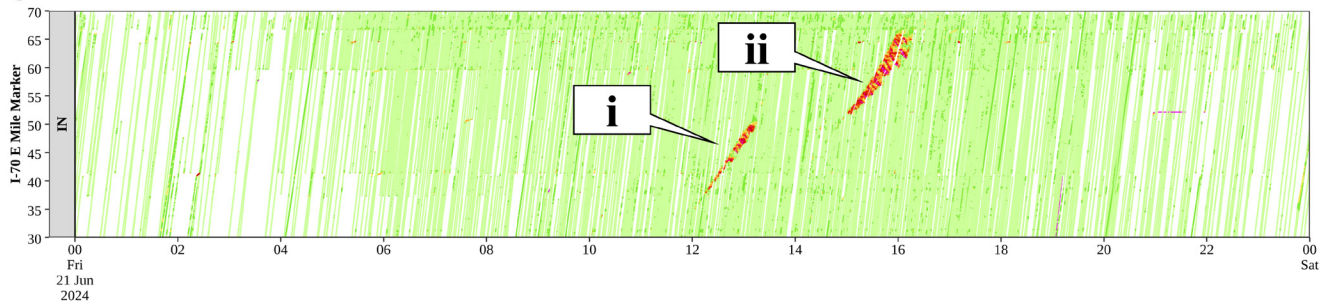
back-of-queue crashes as drivers may not expect stopped traffic during this time.

The opportunity in this case study is to discuss with MOT designers to make sure that if queuing is planned due to lane closures, then advanced signage/messaging is placed and perhaps queue warning vehicles are deployed.



I-70 Indiana

Speed (mph) 0 to 14 - 15 to 24 - 25 to 34 - 35 to 44 - 45 to 54 - 55 to 64 - 65 above



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Figure 2.19 Traffic Speed Heatmap for a Section of I-70 in Indiana from MM 30 to MM 70 on Friday, June 21, 2024.

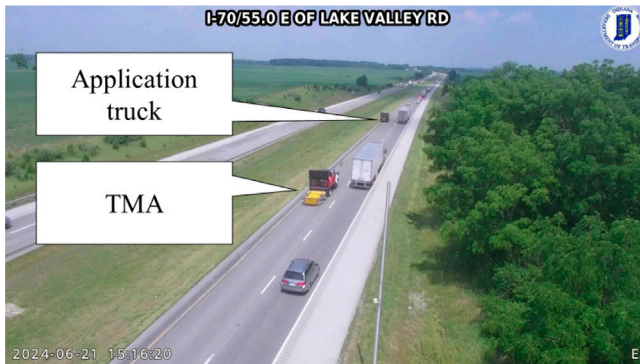


Figure 2.20 ITS Camera Image Showing a Moving Work Convoying in the Left Lane of I-70.

2.8 Case Study VIII: Short-Term Maintenance Activities

2.8.1 Spraying Operation

This case study shows a moving work convoy along the eastbound direction of Interstate 70 (I-70) on June 21, 2024. Figure 2.19 shows a traffic speed heatmap for a section of I-70 with Callouts i and ii showing the congestion from the movement of the spraying operation. A TMA truck and an application truck are using the inside left lane to conduct the work for more than 20 mi. An ITS camera shows an image of the moving convoy at MM 55 (Figure 2.20). This is a good example of how to properly protect the vehicles that are being used to apply the material by using the TMA truck several hundred feet in advance of the vehicles.

The opportunity from this case study is to confirm with TMC operators and DOT officials that this moving work zone is communicated to the motorists as they approach this work convoy.

2.8.2 Moving Maintenance

This case study shows a moving work convoy along the northbound direction of I-65 on October 22, 2024. Figure 2.21 shows a traffic speed heatmap for a section of I-65 with Callout i showing the congestion from the movement of the operation. Two tractors are shown in Figure 2.22 along with a work truck that has a sign stating, “Shoulder Work Ahead.” The likely work being done is mowing or spraying on the outside shoulder which may require vehicles to travel onto and around the shoulder. The potential issue that can arise is if these vehicles need to get around a bridge abutment or a narrow shoulder, they may need to use the travel lane for a brief moment.

The opportunity from this case study is to work with maintenance crews to confirm not only communication with the TMC but to make sure that the protecting vehicle is adequate. If a lane is needed to be taken for the tractors to get around bridges and narrow shoulders, a TMA truck may be the preferred vehicle to provide a higher level of protection.

2.9 Case Study IX: Barrier Wall Installation

This case study shows the installation of a temporary median concrete wall for a work zone along I-65 near MM 256 on June 25, 2025. The installation is being conducted during



I-65 Indiana

Speed (mph) 0 to 14 15 to 24 25 to 34 35 to 44 45 to 54 55 to 64 65 above

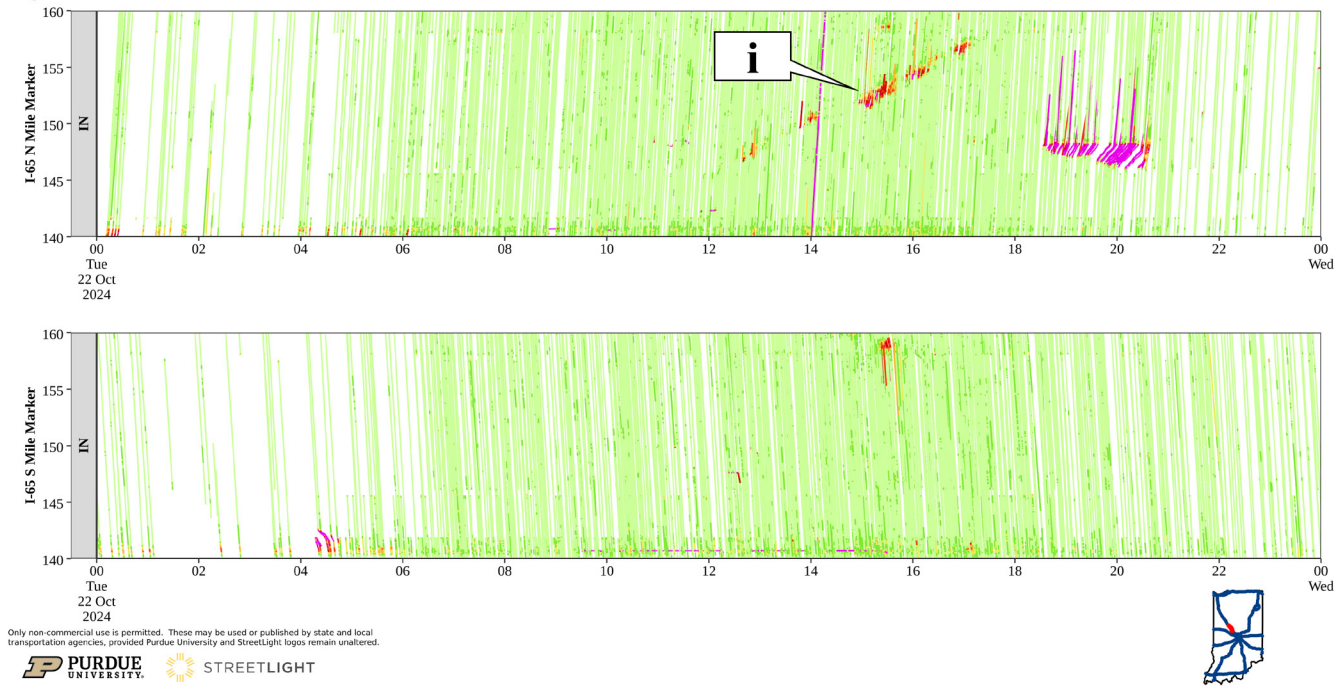


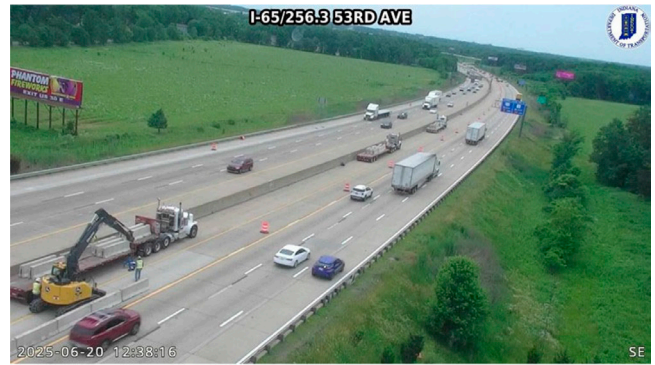
Figure 2.21 Traffic Speed Heatmap for a Section of I-65 in Indiana From MM 140 to MM 160 on Tuesday, October 22, 2024.



Figure 2.22 Dash Camera Image Showing a Semitruck Traveling by a Work Convoy on the Outside Shoulder.

the daytime on a Friday afternoon along a busy stretch of interstate. Figure 2.23 shows two ITS camera images of the concrete barriers being placed next to the live traffic. Normally, the cross section includes three travel lanes with an inside shoulder of 14 ft and outside shoulder of 10 ft. The MOT for this section continues the three travel lanes but has no shoulders on either side. Because of this, vehicles are not able to take evasive actions on shoulders, if needed, and if a vehicle breaks down, has a fire, or is in a crash, there is no relief to go onto either shoulder. The potential issue can arise if any incident occurs and no relief area is provided.

The opportunity from this case study is to work with INDOT and contractors to define the best practice for this type of installation.



(a)



(b)

Figure 2.23 ITS Camera Images Along I-65 Near MM 256.3 on June 20, 2025 Showing the Installation of Temporary Concrete Barriers Next to Live Traffic.

3. OPPORTUNITIES TO IMPROVE EFFICIENCY OF INSPECTION WITH AI AND COMMERCIAL DASH CAMERAS

While dash camera images can allow transportation agencies the ability to virtually drive any and all of their work zones as frequently as needed, the images still need to be inspected and verified manually, which can become labor intensive with the increasing number of dash camera images. Several researchers have looked at the feasibility of using artificial intelligence (AI) for the recognition of traffic signs (Dai et al., 2018; Li et al., 2023; Li & Wang, 2011), but the ability for an agency to implement these models at a scalable level is not currently present.

As part of ongoing studies of work zones, Purdue monitors interstate speeds in nine states in a pooled fund study. Those speeds are collected remotely from connected vehicles and occasionally exhibit anomalies such as queued traffic or, in some cases, total closure (Sakhare et al., 2022). To investigate irregularities in the observed speeds or unexpected queueing, Purdue collects approximately 10,000 dash camera images weekly from commercial trucks across 400 interstate miles in those nine states. Construction work zones are one of the most common anomalies detected in the connected vehicle data and require manual inspection of dash cameras to confirm. To evaluate the feasibility of automating the verification of a work zone, the following AI prompt was submitted to two commercial AI models to analyze a diverse set of 40 images from eight of the partner states:

“Can you analyze these photos one by one from a driver’s perspective and tell me if the driver is in a construction work zone in their direction of travel? Please provide commentary on what you see in the image to support your answer and summarize the results in a table.”

Table 3.1 provides a summary distribution of the 40 dash camera images submitted to the AI models that spanned 20 interstates routes in the eight states. The authors selected 31 images that showed some type of evidence of a construction work zone and nine images where there was no visible evidence

TABLE 3.1
Summary of Images Submitted to ChatGPT o4-mini and Gemini 2.5 Flash.

State	Number of Images in Work Zone	Number of Images Not in Work Zone	Number of Unique Interstate Routes
Delaware	2	0	1
Illinois	7	3	5
Maryland	6	0	3
Michigan	1	3	2
Pennsylvania	4	0	2
Texas	4	1	2
Utah	2	1	2
Wisconsin	5	1	3
Totals	31	9	20

TABLE 3.2
Summary of AI Submission Results.

ChatGPT			Gemini		
Correct	FN	FP	Correct	FN	FP
36	4*		39	1	

Legend

FN: False Negative, did not identify work zone

FP: False Positive, incorrectly identified work zone

*: Two of the False Negatives noted the vehicle was not in a work zone, but approaching one.

of a work zone. Table 3.2 summarizes the results from the AI prompt. Neither of the two models made any mistakes indicating the presence of a construction zone when no construction zone was present (FP). However, there were five errors by the models on indicating that no construction zone was present when, in the authors’ judgement, the image included a work zone. Figure 3.1 shows the response from the models for five images where there was disagreement between the authors and the AI model. With the exception of Figure 3.1c, each of the models responded with information that showed the model recognized the presence of a work zone in the direction of travel but did not say the driver was in the work zone. As shown in Figure 3.1c, the models noted the presence of a work zone on the other side of the road. This, too, seemed to be a plausible response.

4. CONCLUSIONS

The introduction to this report grouped the challenges in work zone MOT into three areas:

1. *Discrepancies between design engineers’ understanding of exiting geometry and actual geometry available:* Areas adjacent to Bridges and guardrail placement can be areas where precision down to the inch are important. Some of these discrepancies are often not identified until construction has begun.
2. *Exception to design policies regarding lane width and shoulders:* As with any design exception, it is critical to ensure proper documentation is in place to support the design exception.
3. *Discrepancies between the MOT design plans and the constructed MOT:* It is important to have effective inspection in place to ensure the designed MOT is implemented, or, in a case when it is not implemented according to design plans, there is appropriate documentation on deviations from MOT designs.

Previous sections of the report provided documentation of several case studies, predominantly focusing on opportunities for improvement. The value of these case studies is that they provide a broad cross section of examples that can serve as valuable training material emphasizing the importance of clear communication and documentation in these three broad areas.

4.1 Candidate Opportunities to Address

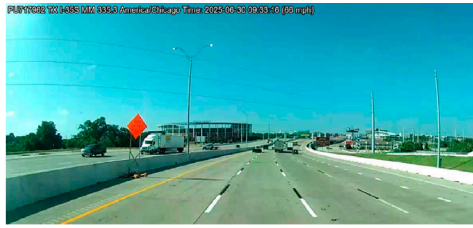
- MOT plans in some cases do not accurately capture the geometry constraints placed by bridges, guardrail and or barrier wall. It is important that design reviews place careful focus on ensuring lane widths, shoulders, and shoulder treatments fit across the entire cross section of each phase or requests for design exceptions be initiated. In some cases, performing some type of LiDAR survey



ChatGPT: No
Orange sign says 'Workers Ahead Next Mile' with 3 barrels on the shoulder. No taper or lane closure visible.

Gemini: Yes
Orange barrels and a "Road Work Ahead" sign are on the right shoulder.

(a)



ChatGPT: No
"Road Work Ahead" sign present, but no barrels or cones in active travel lanes.

Gemini: Yes
An orange construction sign is on the left shoulder.

(b)



ChatGPT: Yes
Concrete barriers line both sides of the lane, and construction equipment is visible on the left. Speed is reduced, indicating a work zone.

Gemini: No
Construction is on the opposite side of the highway, not affecting travel.

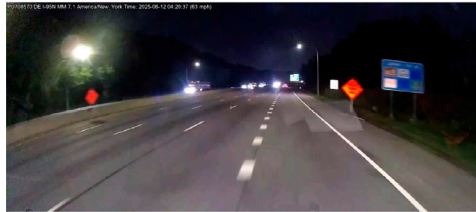
(c)



ChatGPT: Approaching
Two orange warning signs on each side of the highway state "Right Lane Closed 1500 FT"; driver is not yet in the construction zone, but it is imminent.

Gemini: Yes
"RIGHT LANE CLOSED AHEAD" sign is posted and traffic is slow.

(d)



ChatGPT: Approaching
Two orange signs are visible on each side indicating upcoming construction; no barrels or lane closures visible yet.

Gemini: Yes
Orange construction warning signs are posted on both shoulders at night.

(e)

Figure 3.1 Images and AI Responses From Each Model for the Five Images Where the Authors Disagreed With the AI Model. The Response the Authors Disagreed With is Shown as Red Text.

may assist in effectively capturing existing geometry, particularly edge of pavement, edge of bridge, guardrails, and embankments.

- When lane shifts are initiated, the designers should examine the path of the vehicle at both the start and end of the transition. In some cases, the end of the transition occurs quite close to either a guardrail or narrow section of pavement. In some cases, either gentler transitions or additional horizontal clearance should be considered.
- There is relatively little dialog between the temporary traffic control contractors and designers on what are the best practices and requirements for implementing a change in MOT. We recommend a near-term approach of incorporating some of the existing after-actions (I-65: Narrow shoulder, Lane shift taper length, Missing marking and inconsistent markings, and I-65 Variable

work zone speed limit trailer in close proximity to speed limit sign) into one or more of the Fall 2025 Safety Summits to start that dialog.

- To sustain this engagement between designers and MOT contractors, it is recommended that selected projects include MOT review with design engineers and contractors as part of the close-out process to document lessons learned.
- Rolling slows downs have a role in MOT, but there appears to be inconsistent use of rolling slowdowns for short term closures. It is recommended that requirements rolling slowdowns be identified in the MOT plans. If contractors are required to use rolling slowdowns not documented in MOT plans, they should be required to obtain approval from the INDOT and notify the TMC.

- Barrier walls are an important tool for MOT. However, their set up can have significant impact on traffic capacity and create queues. Project plans should define days/time periods these are permitted to be installed and/or removed.
- Most of these case studies used commercial dash cameras to document the case. The use of these is attractive because they can almost immediately be used to replace traditional methods of driving to a site to inspect and can be repeated. However, they do require human review. The final chapter of this report performed a preliminary evaluation of the feasibility of using emerging Artificial Intelligence tools to screen images. Initial tests were quite simplistic, asking about the presence of a work zone, but the results showed considerable promise as the models also identified signs and lane change configurations. Further work in this automated image processing will likely lead to a combination of improved efficiency on screening and quicker feedback to designers, MOT contractors, and prime contractors.

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APPENDICES

Appendix A. List of Acronyms

Appendix A. List of Acronyms

AI	Artificial Intelligence
DMS	Dynamic Message Sign
DOT	Department of Transportation
IMUTCD	Indiana Manual on Uniform Traffic Control Devices
INDOT	Indiana Department of Transportation
ISP	Indiana State Police
ITS	Intelligent Transportation Systems
JTRP	Joint Transportation Research Program
MM	Mile Marker
MOT	Maintenance of Traffic
MPH	Miles Per Hour
MUTCD	Manual on Uniform Traffic Control Devices
PCMS	Portable Changeable Message Sign
TMA	Truck Mounted Attenuator
TMC	Traffic Management Center

About the Joint Transportation Research Program (JTRP)

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

The first studies of JHRP were concerned with Test Road No. 1 — evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

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

Further information about JTRP and its current research program is available at engineering.purdue.edu/JTRP.

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Overall, M. W., Mukai, J., Sakhare, R. S., Desai, J., Horton, D., & Bullock, D. M. (2025). *Case studies documenting lessons learned and identifying opportunities for maintenance of traffic (MOT) improvements* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2025/29). West Lafayette, IN: Purdue University. <https://doi.org/10.5703/1288284318578>