Initial High-Level Assessment of Potential TSMO Strategies

I-80/94 Corridor (Borman Expressway) Transportation Systems Management and Operations (TSMO) Improvements from I-65 to the Illinois/Indiana State Line, Des. No. 1901643

April 2021

CONTENTS

Introduction

The intent of this document is to provide an initial assessment of potential TSMO strategies and to recommend potential strategies that should be investigated further through more detailed traffic analysis as well as a more detailed review of the roadway design.

TSMO is a set of strategies that focus on operational improvements that can maintain and even restore the performance of the existing transportation system before extra capacity is needed. The goal is to achieve the most performance out of the existing transportation facilities. This requires knowledge, skills, and techniques to administer comprehensive solutions that can be quickly implemented at relatively low cost. These strategies and approach may enable transportation agencies to “stretch” available funding to benefit more areas and users. TSMO strategies also help agencies balance supply and demand and provide flexible solutions to match changing conditions.

The benefits associated with TSMO can include:[i]

- Improved quality of life
- Smoother and more reliable traffic flow
- Improved safety
- Reduced congestion
- Less wasted fuel
- Improved air quality
- Increased economic vitality
- More efficient use of resources (facilities, funding)

TSMO looks at performance from a systems perspective, not just one strategy, project, or corridor. This means that these strategies are coordinated with other potential initiatives across multiple jurisdictions, agencies, and modes. Integration views the surface transportation network as a unified whole, making the various transportation modes and facilities work together and ultimately perform better. TSMO not only provides public agencies with a growing toolbox of individual solutions but encourages combining possible solutions to achieve greater performance over the entire system. Integration can occur on multiple levels:[ii]

- System – Implementing and combining strategies as a corridor or region matures.
- Technical – Developing a framework used to support information sharing between different technologies deployed on the system.
- Cultural – Developing a workforce that values and prioritizes the use of TSMO solutions across multiple disciplines.
- Operational – Coordinating day-to-day operational strategies that allows corridor, region, or system-wide objectives to be achieved.
- Institutional – Incorporating TSMO policies and processes into an agency's normal way of doing business. This step includes TSMO integration with various disciplines, such as planning, program management and design, to support long-term goals for the transportation system. This step can also be applied both internally and externally.

While many TSMO strategies do have a significant technology component, the TSMO toolbox is not limited to just technology. Operational enhancements and design treatments should also be used to improve the performance of the transportation system. Accessible shoulders, restriping, emergency access, and snow fences, for example, are also relevant TSMO strategies.

While agencies may already be using some of these solutions, TSMO is not limited to deploying a single strategy. Intelligent Transportation Systems (ITS), for example, represent just one set of tools for managing and operating the transportation system. TSMO does leverage technology, a toolbox of strategies, and engineering solutions to maximize the performance of the system. However, TSMO ultimately involves a mindset to determine the best way to optimize the mobility and reliability of the existing system with limited resources. TSMO implementation needs to include planning, design, people, processes, technology, and data.[iii]

Existing Conditions Overview

Roadway Infrastructure

The limits for this study extend along the I-80/94 Borman Expressway corridor from west of the Indiana/Illinois state line to I-65, a distance of approximately 11.5 miles. The land use adjacent to the corridor is highly urbanized with a mixture of residential and commercial properties. The presence of adjacent wetlands and water features increase from west to east and especially approaching the eastern study limits.

The corridor consists of primarily four (4) through, "general purpose" lanes in each direction with auxiliary lanes and ramp lanes throughout the entire corridor. Inside and outside shoulder widths vary from 11.8 feet to 14 feet. It is noted that the western portion of the project was designed in metric units, thus the unique shoulder width of 11.8 feet. Moving further east, the inside and outside shoulders increase to 14 feet.

There are seven (7) service interchanges and one (1) system interchange, with I-65, within the study limits. The following are the services interchanges within the study area:

- I-80/94 with Calumet Avenue/US 41
- I-80/94 with Indianapolis Blvd./SR 152/US 41
- I-80/94 with Kennedy Avenue
- I-80/94 with Cline Avenue/SR 912
- I-80/94 with Burr Street
- I-80/94 with Grant Street
- I-80/94 with Broadway/SR 53

There are 10 mainline bridges and 60 structures (bridges and large culverts) within the study corridor. At several locations throughout the study corridor, the median barrier width increases to accommodate an existing bridge pier, and for overhead structure foundations. Noise walls are present along both directions for a portion of corridor. The existing roadway pavement is concrete, however patching is needed for a large portion of the study corridor.

There are several utilities near and crossing this segment of the study corridor. There are many large overhead transmission lines and natural gas lines. Natural gas, water, and fiber is also present within most of the service interchanges. There are seven (7) rail lines that are crossed by the freeway. The freeway facility is also equipped with continuous lighting along the majority of the study corridor and high mast lighting is present at some interchanges.

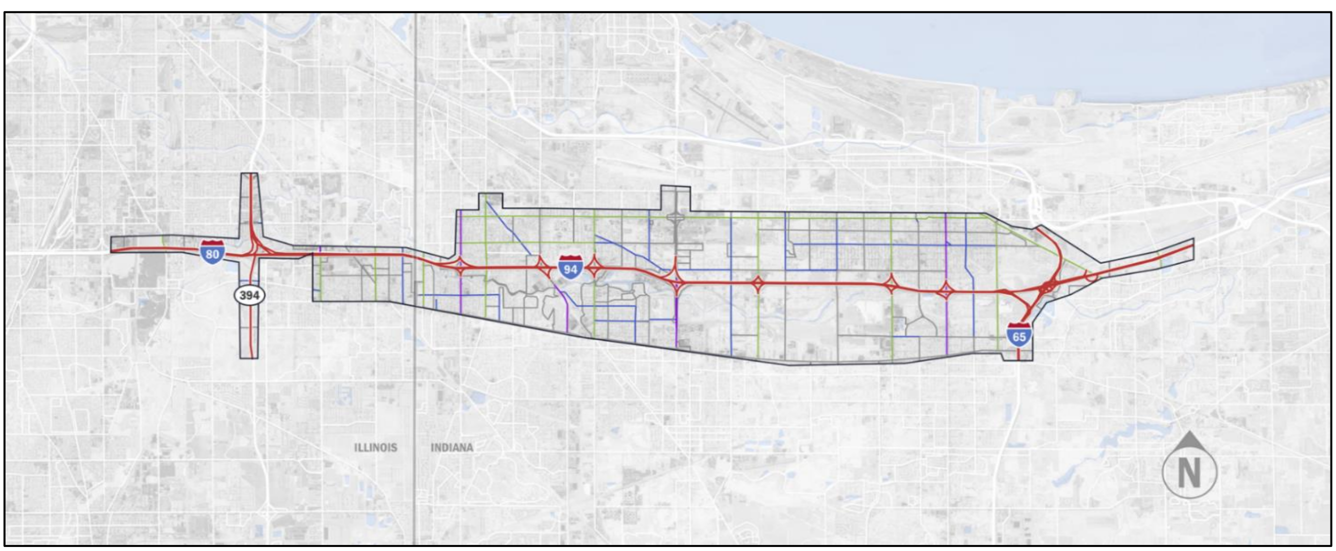


Figure 1: I-80/I-94 Model Scope Area

Existing ITS Infrastructure Overview

The project area is instrumented with ITS field devices, including CCTV cameras, dynamic message signs (DMS), mainline vehicle detection, Road Weather Information Systems (RWIS), fiber optic and radio communications systems, and Travel Time System (TTS) signs. Of particular importance are the existing devices that can support TSMO strategies, such as DMS, CCTV, and mainline vehicle detectors, along with the communications and power infrastructure to serve future roadside devices that may accompany each TSMO strategy. It is also important to note the locations of existing field infrastructure, particularly the backbone fiber optic cable, and the preservation of devices and communications during the construction of any TSMO strategy, as well as the need to minimize down time.

In Figure 2 below, the locations of existing truss mounted DMS and shown. Locations for DMS in Illinois are also shown in Figure 3, as they will play a key role in informing motorists approaching the project area from the west. Both IDOT and INDOT DMS are similar in size and technology and are all mounted on gantries over the mainline lanes. All DMS have hard wired power connections and are backhauled over fiber optic cable.

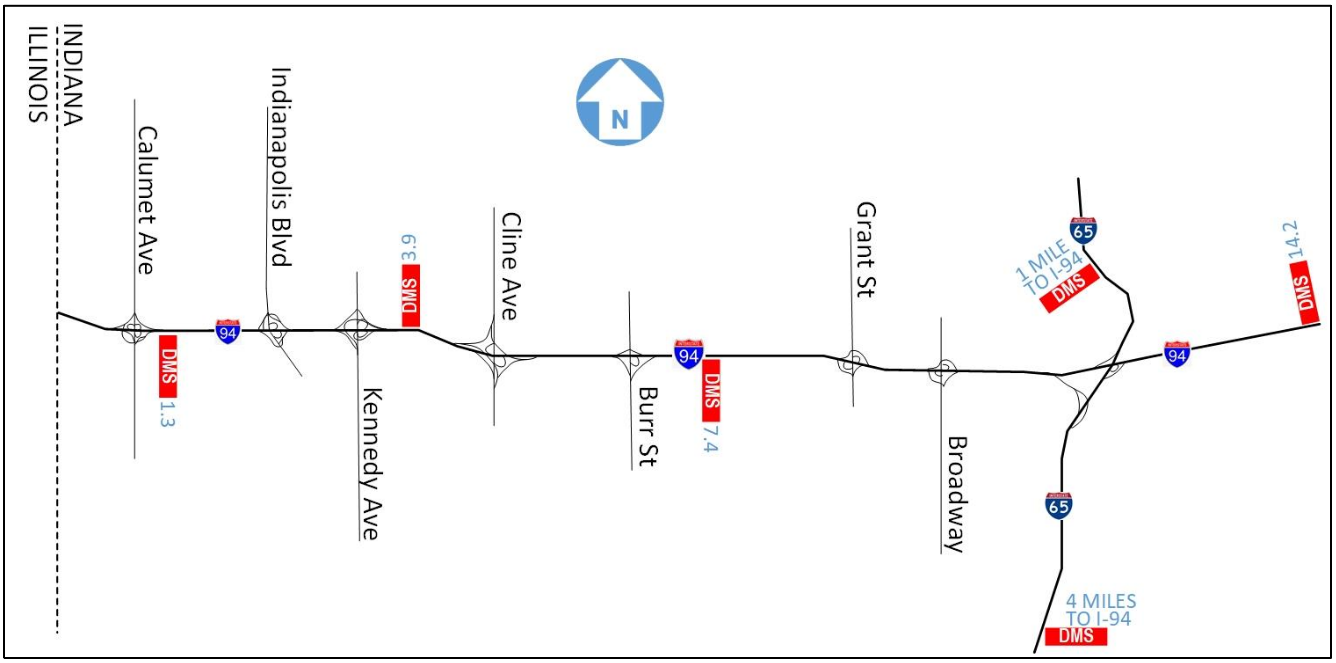


Figure 2: Existing Truss Mounted DMS Locations in Indiana

Three INDOT DMS are installed throughout the corridor, with a fourth westbound DMS located approximately 2.2 miles beyond the eastern project limit at I-65. Additional DMS on I-65 are well placed to provide information to motorists entering the study corridor from I-65 or the Indiana Toll Road. IDOT DMS are also placed at locations to provide useful information to motorists approaching the corridor from the west on I-94, I-294, and I-80. However, the existing DMS near the I-80/I-294 interchange is located approximately eight (8) miles west of the project limits, which may be too far to provide relevant information and may warrant the need for an additional sign located in between the existing DMS and the western study limits.

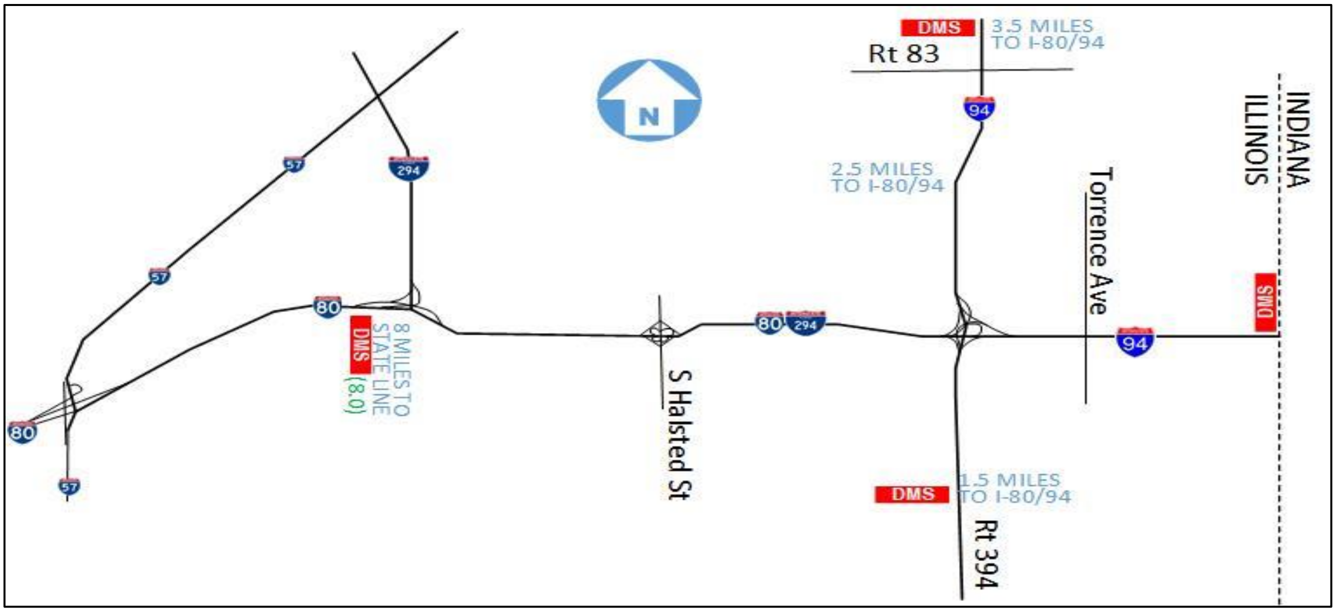


Figure 3: Existing Truss Mounted DMS Locations in Illinois

Vehicle detector locations are shown in Figure 4 for the Indiana portion of the project. Detectors are side fired microwave radar detectors installed at roughly half mile intervals. All except four detectors are hard wired to a power source. Detectors installed outside the eastbound shoulder are connected to fiber optic cable. Most westbound detectors use radio communications, whereas others are connected to the fiber backbone. It is noted however, that most of the microwave detectors are old and may soon need to be replaced. Furthermore, it has been suggested that the ITS team plans to install new vehicle detection as needed for any project stemming from this study.

Figure 4: Existing Detector Locations

CCTV cameras are installed on both the Indiana (Figure 5) and Illinois (Figure 6) sides of the corridor providing nearly full surveillance coverage of the freeway when utilizing the full zoom capabilities of the cameras. However, the existing CCTV coverage is not adequate for a quick review of the entire corridor, as would be needed for some potential TSMO strategies.

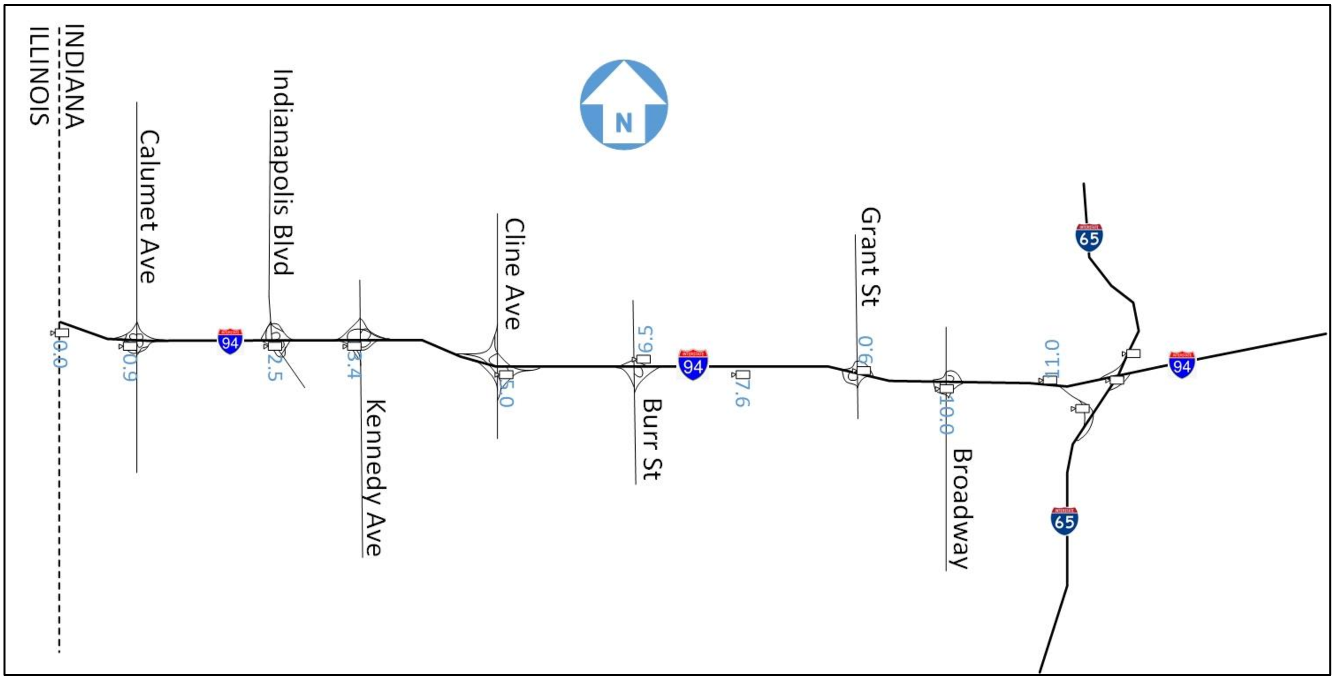


Figure 5: Existing CCTV Camera Locations in Indiana

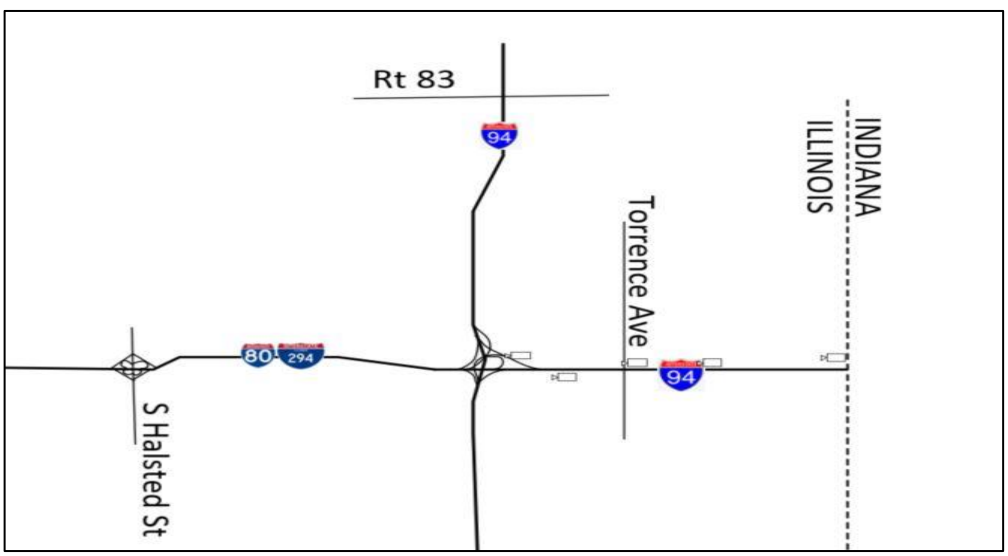


Figure 6: CCTV Camera Location in Illinois

All camera locations are hard wired to a power source and are connected to fiber optic cable.

Within the Indiana segment of the study corridor, fiber optic trunk cable extends the length of the highway segment connecting devices to the Borman TMC which is located a few miles east of the study corridor limits, adjacent to the Ripley Street Interchange. The INDOT fiber cable is located along the southside of the highway and is installed in the shoulder for much of the western half of the study area. Otherwise, the fiber cable is installed off the shoulder. An excerpt from the "as-built" fiber optic design plans is shown below in Figure 7.

Figure 7: Fiber Optic Trunk Cable Location

Fiber cable is installed in a 4" HDPE conduit with 1-1/4" innerducts. Smaller conduits are used to make the connection between equipment cabinets and the main conduit containing the fiber optic trunk cable. Two 96-fiber cables are installed in two separate conduits, providing a measure of redundancy and automatic failover. Tap ins to the fiber optic trunk cable are made at fiber optic vaults, where long pre-terminated jumper cables are connected between the trunk cable and a fiber patch panel located in the provided equipment cabinets.

Communication services are aggregated at the roadside equipment shelter at the Illinois/Indiana border and at the Borman TMC. Another shelter is located on I-65 just south of the study corridor. The border shelter is shown in Figure 8 below.

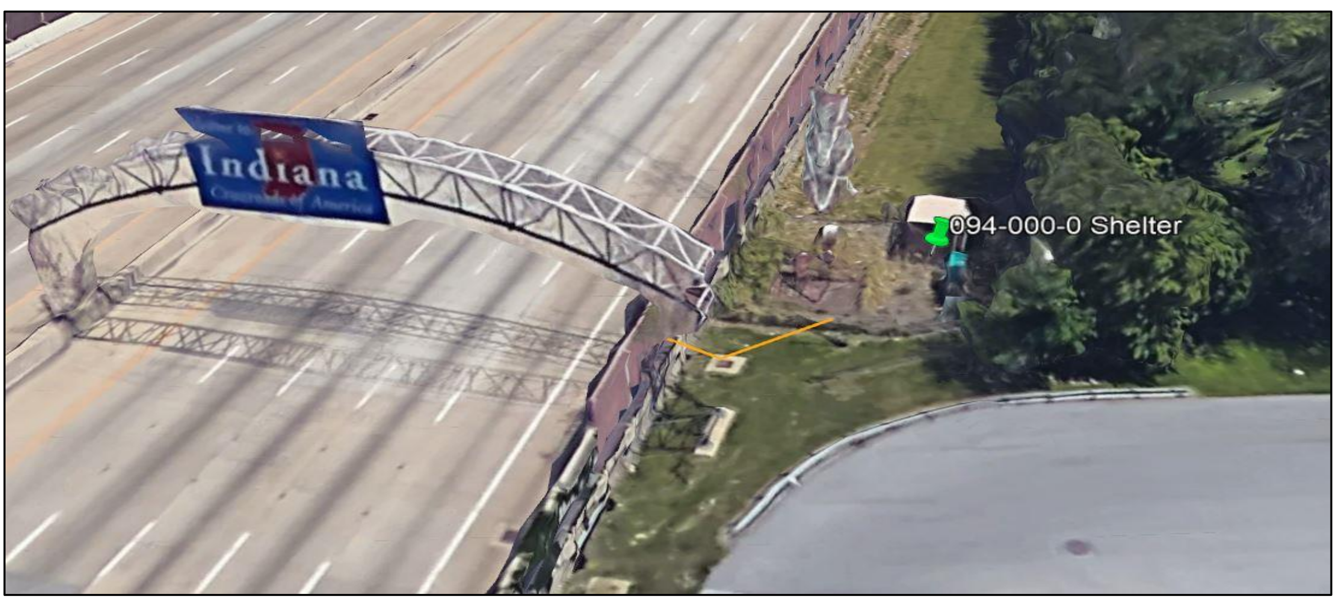


Figure 8: Communications Aggregation Shelter Location

Within the Illinois segment of the study corridor, the fiber optic cable is installed in the median. The IDOT fiber cable runs along the median to the Indiana border and is terminated in a communications shelter on the north side of the freeway. There is no physical connection between the two agency systems. The photo in Figure 9, shows the location of the INDOT and IDOT communications shelters at the state line.

Figure 9: Border Locations of Illinois and Indiana Communications Shelters

The INDOT fiber cable runs along the Indiana Toll Road for a short segment between I-65 and the Gary TMC. Several options exist for making a fiber connection between the two agencies, such as making the connection in the INDOT communications shelter at the I-65 interchange with the Toll Road (see Figure 10). The Toll Road fiber cable is terminated just north of the communications shelter in the toll plaza building.

Figure 10: Potential Fiber Connection with Indiana Toll Road

Existing Traffic Overview

As background for the identification of applicable Transportation Systems Management and Operations (TSMO) strategies, an overview of the existing traffic characteristics is provided along with a high-level summary of the collision history.

Traffic Characteristics

The predominantly eight lane freeway between the study limits is heavily traveled during both the AM and PM weekday peak periods as the typical peak hour volumes summarized in Table 1 below illustrate. The peak direction of traffic flow during the AM peak period is westbound and the peak direction of traffic flow during the PM peak period is eastbound. However, there is not a substantial directional flow. Generally, the PM peak hour volumes are higher than the AM peak hour volumes.

Table 1: Typical Weekday Segment Traffic Volumes (2019)

Location	AM		PM	
	WB (vph)	EB (vph)	WB (vph)	EB (vph)
West of Calumet Avenue	5300	4730	5380	6380
East of Calumet Avenue	5370	4850	5500	6340
East of Indianapolis Blvd	5560	4920	6120	6540
East of Kennedy Avenue	5390	4970	6130	6280
East of Cline Avenue	5600	4920	6050	6670
East of Burr Street	5420	4920	6070	6370
East of Grant Street	5250	4900	5960	6360
East of Broadway	5080	4720	5580	6240
East of I-65	3390	2850	3810	3620

Freeway ramp traffic volumes have also been summarized at all interchange locations along the study corridor as shown in Table 2 below. High entrance and exit ramp volumes (>800 vph) have been highlighted in red.

Table 2: Peak Hour Ramp Traffic Volumes

Interchange Location	AM Peak Hour				PM Peak Hour			
	Westbound		Eastbound		Westbound		Eastbound	
	Entrance (vph)	Exit (vph)	Entrance (vph)	Exit (vph)	Entrance (vph)	Exit (vph)	Entrance (vph)	Exit (vph)
I -294 Interchange	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Torrence Avenue	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Calumet Avenue	965	1040	850	730	965	1080	1120	1155
Indianapolis Blvd	510	705	630	560	830	625	1010	810
Kennedy Avenue	640	465	400	345	545	560	555	820
Cline Avenue	1110	1315	920	975	1195	1115	1585	1195
Burr Street	410	235	300	300	375	395	320	615
Grant Street	390	215	350	370	450	340	455	460
Broadway	430	260	245	420	595	215	470	600
I-65 Interchange	470 2010	795	600	2210 261	1975 610	820	735	3000 355

Between the high mainline and ramp traffic volumes, the study corridor regularly experiences congestion during the weekday peak periods as shown in Figure 11 and Figure 12 below which depict the travel speeds (by color) along the study corridor for two representative weekdays in April 2019 (AM Peak) and September 2019 (PM Peak). As can be seen in the two figures, there are few reductions in travel speed during the AM Peak Period in either direction of travel throughout the length of the study corridor, with only a reduction noted in the westbound direction in the vicinity of the merge from I-65 (Figure 12). However, in the PM Peak Period, reductions in the travel speed in the westbound direction are observed in the vicinity of the merge from I-65 (Figure 11). In the eastbound direction, several locations along the study corridor experience congestion during the PM peak period.

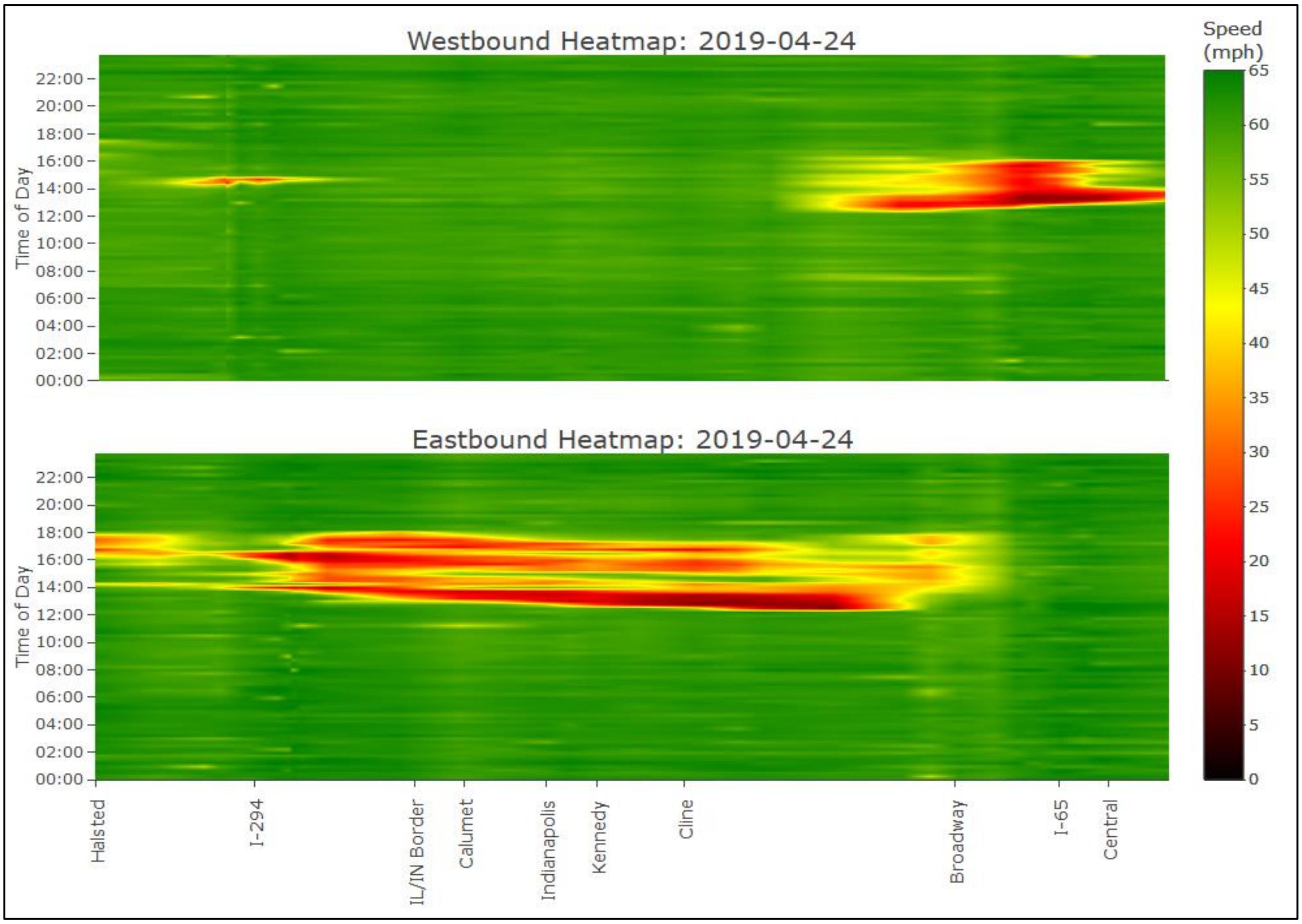


Figure 11: Corridor Heat Map (Speeds) for Representative Day Weekday - April 24, 2019

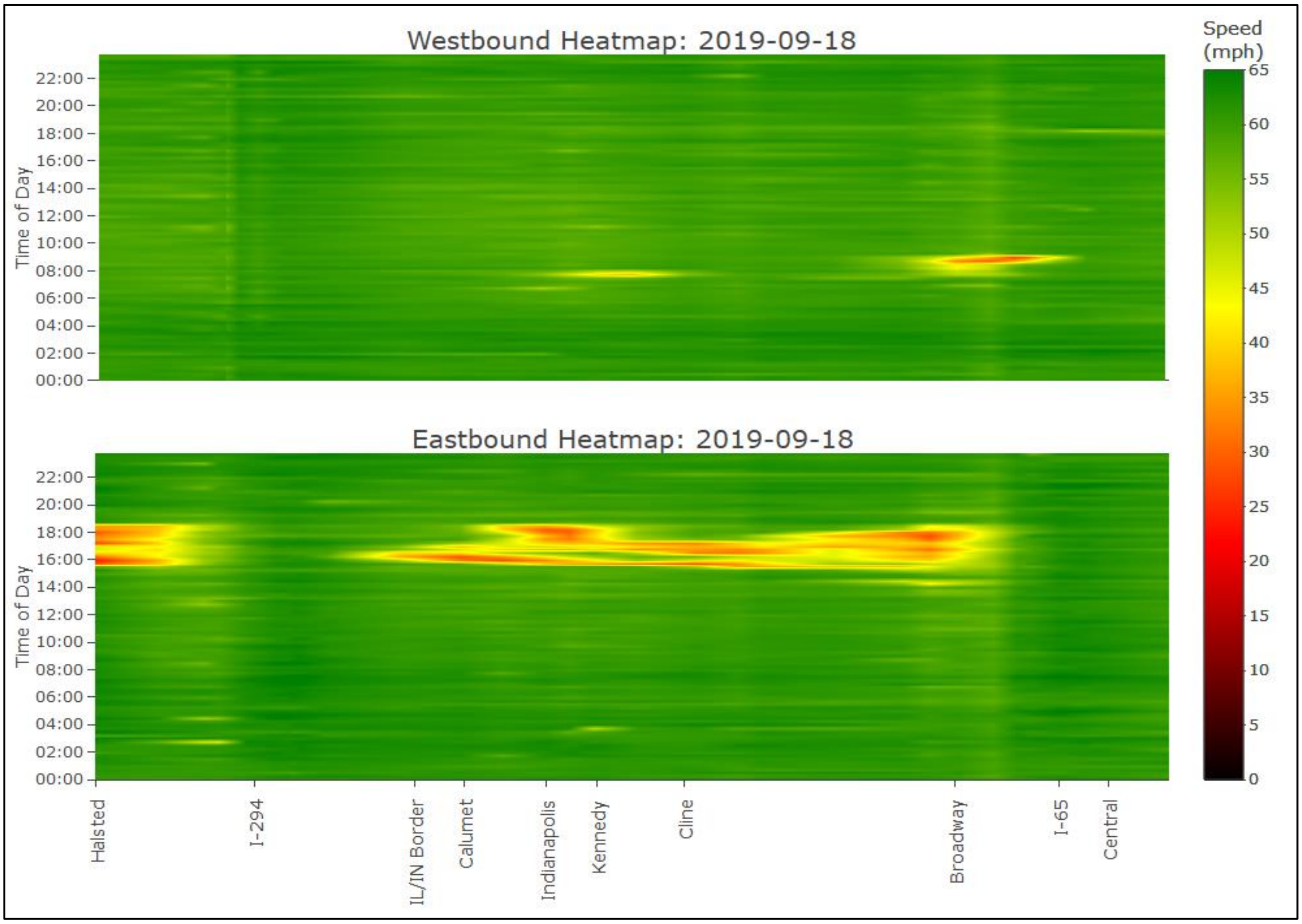


Figure 12: Corridor Heat Map (Speeds) for Representative Weekday - September 18, 2019

The travel patterns also change significantly during the year with seasonal peak periods occurring during the summer and around weekend days – Friday afternoons / evenings and Sunday. As can be seen in Figure 13 and Figure 14, significant congestion is noted in both directions of travel on a representative Friday afternoon / evening and representative Sunday – both in August 2019.

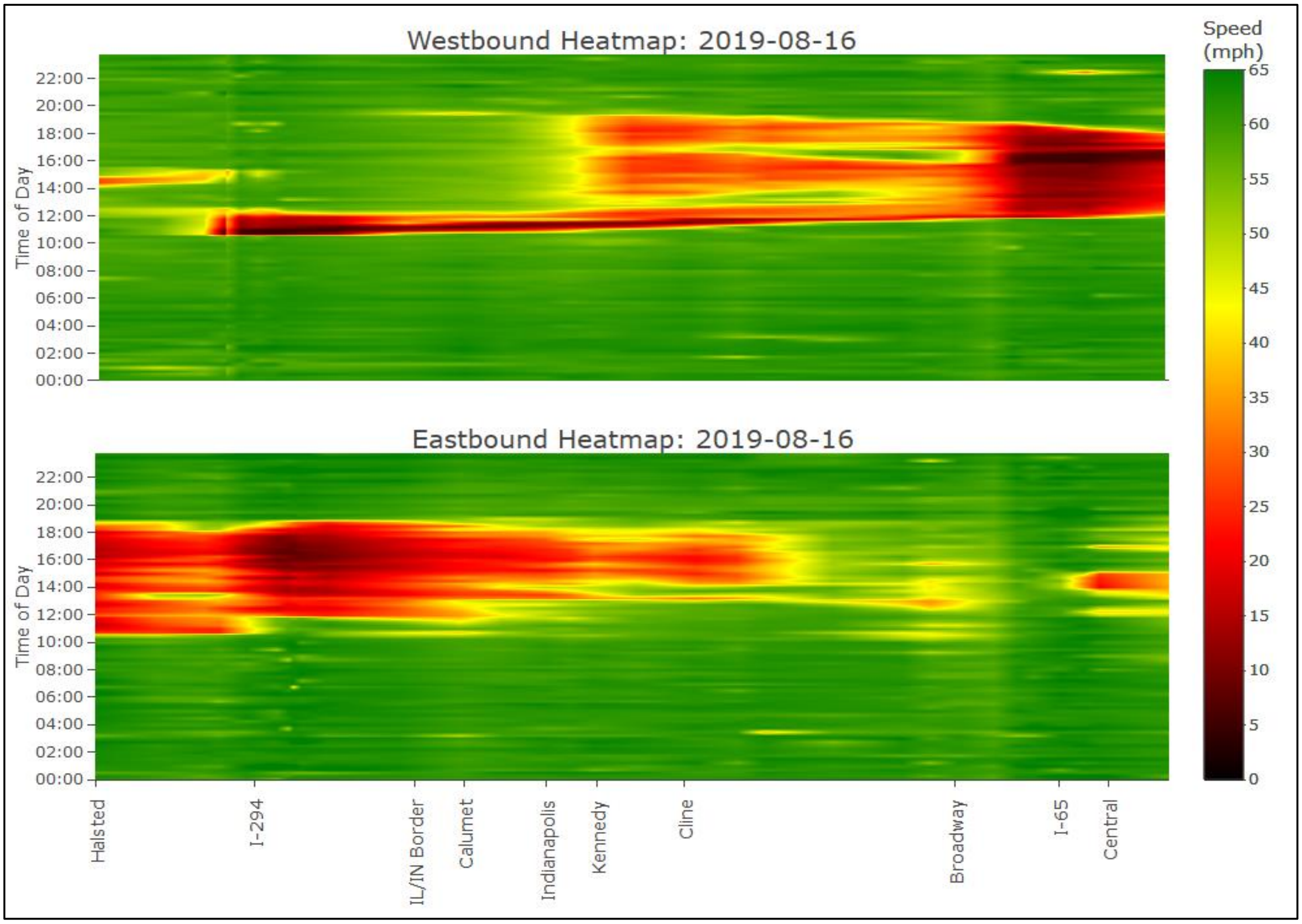


Figure 13: Corridor Heat Map (Speeds) for Representative Friday PM - August 16, 2021

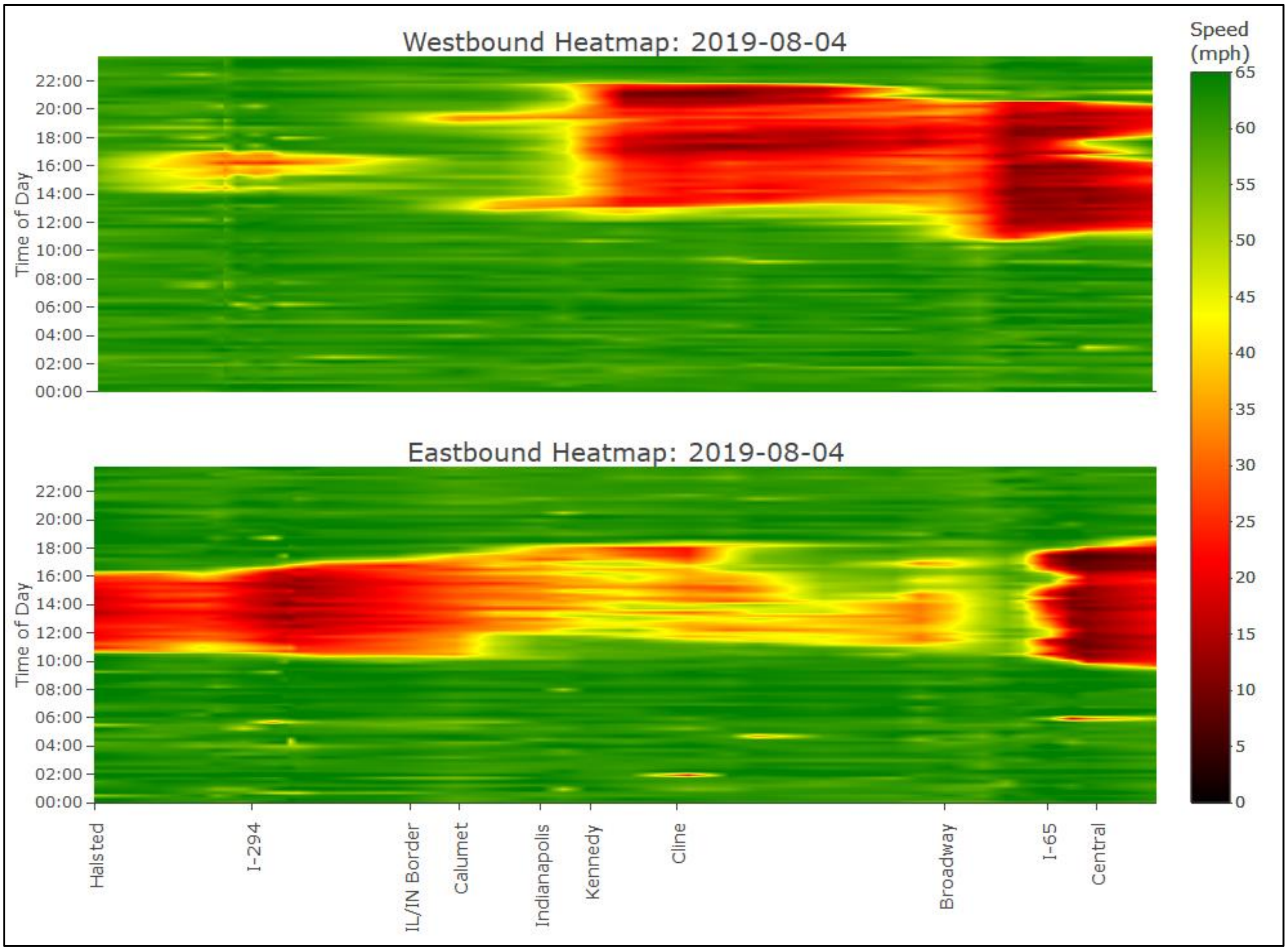


Figure 14: Corridor Heat Map (Speeds) for Representative Sunday - August 4, 2019

Compounding the high traffic volumes along the study corridor is the large number of large trucks within the traffic stream. Estimates of the average truck percentage on a daily basis is shown in Table 3 below. As can be seen, trucks represent upwards of 30% of the overall traffic stream in some sections of the study corridor.

Table 3: Truck Percentages (Daily Average)

Location	WB %	EB %
West of Calumet Avenue	26	24
East of Calumet Av	31	30
East of Indianapolis Blvd	27	28
East of Kennedy Avenue	27	26
East of Cline Avenue	23	28
East of Burr Street	26	26
East of Grant Street	24	14
East of Broadway	28	26
East of I-65	16	21

Traffic Safety Summary

A summary of the collision history along the study corridor between 2017 and 2019 is shown in the Figure 15 in terms of collision frequency per mile segment.

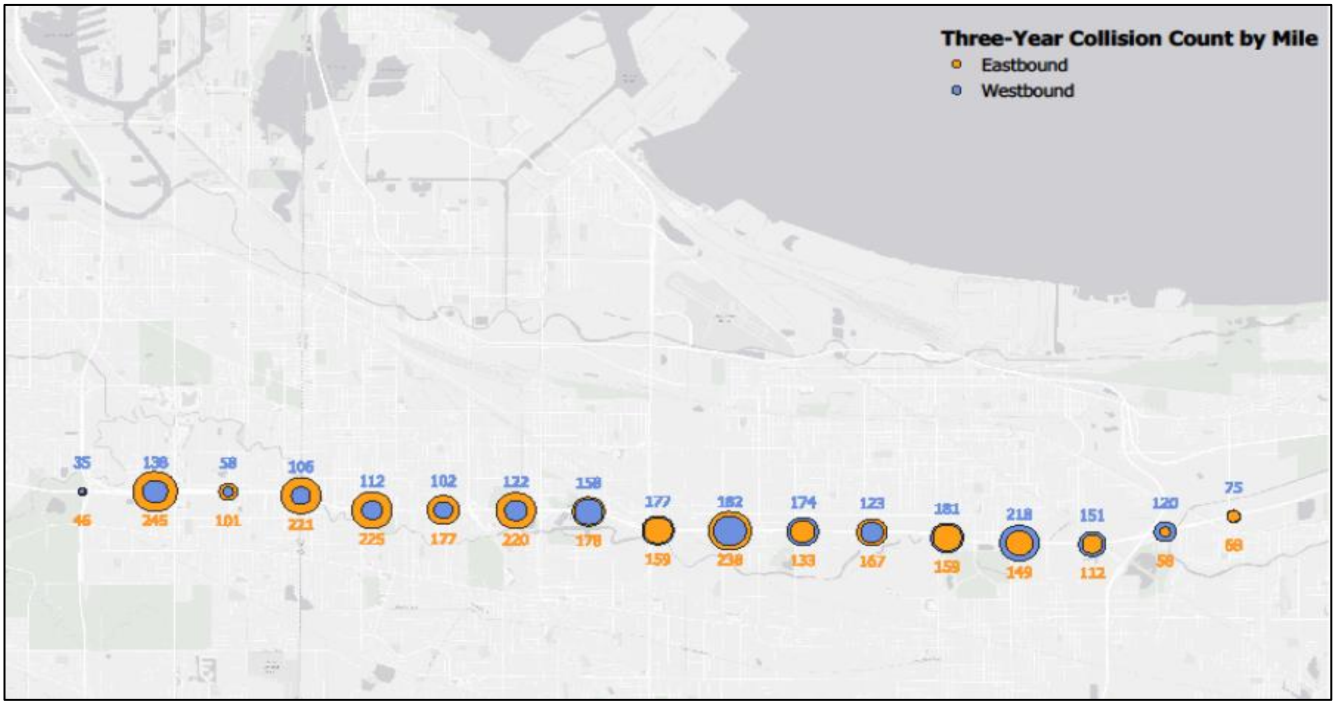


Figure 15: Collision History Summary 2017-2019

As can be seen in the above figure, collisions are somewhat evenly spread along the study corridor with a slightly higher number of collisions having occurred in the vicinity of the following interchanges:

- Torrence Avenue Interchange (381 collisions)
- Burr Street Interchange (420 collisions)
- Broadway Interchange (357 collisions)

Further assessment of the collision history also indicated that trucks seem to be overly represented in the collisions occurring within the study corridor as illustrated in Figure 16 below:

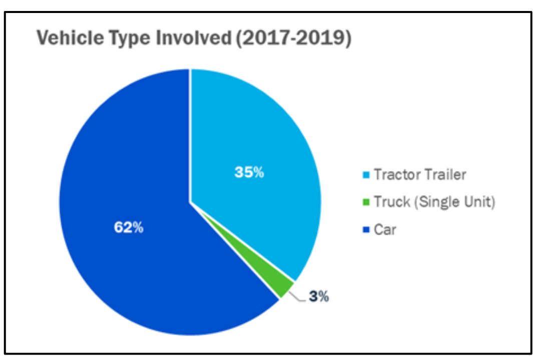


Figure 16: Collisions by Vehicle Type

TSMO Evaluation Process

An initial assessment of potential TSMO strategies that may be applicable to the corridor is the primary intent of this report. The assessment was based on the result of interviews with key operational, traffic, and maintenance staff in the region as well as an initial investigation of the freeway geometrics and other existing conditions within the study corridor. This assessment will assist in narrowing down the longer list of potential TSMO strategies with the more applicable or preferred strategies being evaluated in further detail in the subsequent phase of the study. Strategies that do not appear to be readily deployable, do not appear to provide enough value, or have “fatal flaws” that cannot be readily overcome, will be removed from further consideration.

Within this document, several preferred strategies have been identified and a description of the each of these strategies have been provided along with a discussion on the key issues that need to be addressed. During the next phase of this project, the potential issues identified for each strategy will be addressed through detailed traffic analysis (as applicable) and the development of a Concept of Operations which will consider a set of preferred strategies.

The following section provides a prioritized list of potential TSMO strategies based on the input provided through the agency staff interviews, initial data collection, and site assessments. Following the preferred strategy list, the strategies that have been removed from further consideration are summarized.

Again, it is important to note that this initial assessment is only to assist in narrowing down a larger list of potential TSMO strategies and that a more detailed evaluation of the more applicable strategies will be conducted in the subsequent phase of the study to determine a final set of preferred TSMO strategies that together, will improve traffic operations and safety within the corridor as well as maintenance and associated operations.

Short Listed Strategies

Dynamic Shoulder Lanes (DSL) / Hard Shoulder Running (HSR)

Dynamic Shoulder Lanes: This strategy enables the use of the shoulder as a travel lane(s), known as Hard Shoulder Running (HSR) or part time shoulder use. The use of the shoulder lane is typically based on congestion levels during peak periods and in response to incidents or other conditions as warranted during non-peak periods. In contrast to a static time-of-day schedule for using a shoulder lane, an ATDM approach continuously monitors traffic conditions and uses real-time and anticipated congestion levels to determine the need for using a shoulder lane as a regular or special purpose travel lane (e.g., transit only).

CORRIDOR SPECIFIC DETAILS

From discussion with INDOT and IDOT traffic, operations, and maintenance staff, there is interest in considering the use of both the inside and outside shoulders. The sections below address the potential use strategies for the inside and outside shoulders as well as the considerations, issues and items that need further investigation to derive the final solutions.

Inside Shoulder Use

The inside or median shoulder runs continuously for the length of the study corridor from just east of Torrence Avenue to the I-65 interchange. The ability to use the inside shoulder as a travel lane during peak traffic periods could provide significant benefits to traffic flow and reliability. The optimal solution would allow for the use of the inside shoulder for the entire length of the project during peak traffic hours – in both directions of travel.

Operational Considerations

All of the stakeholders interviewed expressed support for the use of the inside shoulders during peak traffic periods. However, several operational and maintenance issues need to be considered and addressed as part of this strategy:

- Safe and efficient opening and closing of the shoulder lane.
- Removal of debris along the shoulder.
- Winter maintenance and snow removal.
- Potential for shoulder flooding and drainage system maintenance.
- Shoulder speed limits in general, and in comparison, to the mainline lanes.
- Ingress and egress locations and design.
- Providing appropriate operational staff to manage the use of the lanes and provide additional needed maintenance.

Noting the high traffic volumes within the study corridor and the presence of recurring congestion at several locations during the weekday peak periods, it is anticipated that use of the inside shoulders for through traffic will improve corridor traffic operations and overall throughput. Traffic analysis though application of the traffic operation model (micro-simulation) will be undertaken to estimate the changes in traffic performance and associated benefits to the overall traffic stream.

Physical Infrastructure Considerations

Through initial site and plan reviews, several field infrastructure related issues were identified that will need to be addressed to utilize the inside shoulder during peak traffic periods or incidents.

- I-80/94 inside and outside shoulder widths vary throughout the study corridor. Both shoulders widths are 11.8 feet at the western end of the study limits and widen out to 14 feet at the eastern end of the study limits.
- The median barrier widens at overhead signs structures and at some bridge pier locations that in turn, reduce the width of the inside shoulders by ~1.0 feet in each direction.
- Existing drainage structures are present in the median shoulder. Inlet Type H with and without slotted drain pipe are common. The slotted drains will need to be removed as it is anticipated these will be crushed under traffic. Removal of these drains could have an adverse effect on the surrounding pavement and the drainage capabilities.
- Additional drainage structures will most likely be required unless use of the shoulder lane is restricted during rain and snow events.
- There are concerns that load transfer tie bars are not present in either shoulder. This issue can be remedied with expensive retro fitted joints but this work is labor intensive, and time consuming to perform. Load transfer tie bars may not be required if trucks are restricted from the shoulder lanes and the shoulder lanes have limited hours of operations. Coordination of this pavement element with INDOT pavement design will be required, however, restricting trucks from the shoulder lane through signing ("No Trucks") will most likely be a mitigation strategy.
- Preliminary calculations show that three (3) of the horizontal curves within the study corridor do not meet current standards for super-elevation rates for a design speed of 65 mph. Also, the high side shoulder breaks in the wrong direction for travel. It may be necessary to reconstruct the pavement in these locations to achieve proper superelevation, which may result in some of the median barrier needing to be bifurcated. The superelevation transition at these subject curves also will not meet current standards.
- There are existing ITS features within the pavement. This equipment will need to be considered if reducing lane widths is to be proposed to accommodate additional width for shoulder use.
- Many existing bridge abutments and piers, retaining walls and noise walls fall within the zone of intrusion "ZOI." It is highly unlikely that the project would have the available funds or necessary R/W to rebuild all of these features so a waiver would need to be provided.
- Existing constraints such as noise walls and R/W, will need to be considered when identifying locations for new overhead sign structures for lane control.

- Considering the likely reconstruction project in 2035 to 2040, consideration should be given to ensuring that all new overhead sign structures are constructed with the repaving project in mind, such that the signs do not need to be reconstructed. It is understood that the State would like to bring all the mainline lanes back up to the standard width of 12 feet with the reconstruction project.
- ITS fiber and conduit are located in the median within the Illinois portion of the study corridor. Since this location is at the far end of the IDOT system, the impact of a potential cable cut will only affect the local devices in the area. To minimize down time and to keep the Illinois ITS equipment operational, temporary fiber or radio links can be installed to keep these devices operational.

Items That Have Been Cleared

- Bridge vertical clearances. It appears that adequate vertical clearance is provided along the entire length of the study corridor.
- Utilities – No significant changes are being proposed to the pavement and area below the original ground surface with the exception of potential changes to the drainage. At this time, it is anticipated that there will be limited impacts to any existing utilities within the study corridor. For new sign foundations, it is likely there would be flexibility to shift the location of the signs in order to avoid any utility conflicts.
- Lighting – Lighting along the corridor and ramps is not seen as an issue at this time. However, if widening along the ramps is required, lighting upgrades may be warranted.

Outside Shoulder Usage

Operational Considerations

Throughout the corridor, in both directions of travel, the lane configuration changes back and forth between four lanes and four lanes plus an auxiliary lane. These auxiliary lanes extend between the on ramps and drop at the next off-ramp – at each interchange. If traffic is allowed to use the outside shoulder in areas with auxiliary lanes, there is the potential for weaving issues to arise in the section prior to the off ramps, where vehicles continuing through on the corridor would cross over vehicles exiting the corridor at the off ramp.

Throughout most of the corridor, right shoulder lane widths vary from 14 feet down to 10 feet. Sections of the corridor on the far west end, in Illinois, have 10-foot shoulders. In addition, much of the corridor has sound walls on the outside edge of the right shoulder which further constrains the available width for potential use as a travel lane. These sound walls line the majority of the study corridor in both directions and their presence results in several maintenance issues including:

- In the winter months, snow accumulates up against the sound wall and can occupy a significant portion of the shoulder, and
- Debris is common on the outside shoulder.

The above conditions are not conducive of using the shoulder throughout the peak periods. However, there is the potential to use large portions of the right shoulder as needed to get vehicles around significant accidents or lane closures that have a large impact on free flow traffic conditions.

Looking past the maintenance issues, the high corridor traffic volumes and presence of recurring congestion at several locations during the weekday peak periods suggest that use of the outside shoulder may provide additional capacity for through traffic. However, as noted above, the use of auxiliary lanes between the entrance and exit ramp terminals will create complexities in the treatment of entering and exiting traffic. Also, it is noted that there is significant truck traffic in the right three lanes throughout the day in both directions of travel.

If considered as an appropriate strategy to improve traffic operations, further traffic analysis though application of the traffic operation model (micro-simulation) can be undertaken to estimate the changes in traffic performance and associated benefits to the overall traffic stream.

Physical Infrastructure Considerations

- Outside shoulder widths vary between 10 feet and 14 feet, except at the western extremities of the study corridor.
- Trucks typically use the right two "general purpose" lanes, therefore those lanes are required to be 12 feet and should not be reduced to accommodate a wider outside shoulder.
- Sound walls line a significant portion of the roadway in both directions.
- There are concerns that there are no load transfer tie bars in either the inside or outside shoulder. This can be remedied with retro fitted joints, but this approach is expensive and time consuming. It is anticipated that the shoulders will be signed to restrict trucks (i.e., "No Trucks"), however, it is anticipated that trucks will comply with the restrictions for the inside shoulder lanes, but may not fully comply with the truck restrictions proposed for the outside shoulder lanes. Allowing trucks on the outside shoulder could have significant cost implications.
- ITS – there are existing handholes in the shoulder (specifically the Indiana side) and these handhole will likely be in the wheel paths. Relocation of these handholes will likely be required.

Items That Have Been Cleared

- According to the existing plans, the existing overpass structures have adequate vertical clearances.
- Utilities – Further investigations will need to occur during final design but no significant utility impacts are anticipated at this time. The proposed work is not anticipated to occur below the existing pavement depth (except drainage in the median), other than proposed sign foundations. For new sign foundations, it is assumed there would be flexibility to shift the location of the signs in order to avoid any utility conflicts.
- ITS –There is conduit located in the outside shoulder. This conduit is not anticipated to create an issue as the depth of the conduit should be below the existing subgrade.
- Lighting – It is anticipated that existing lighting will be affected in locations where barrier is to be removed and reconstructed. No additional lighting is anticipated.

PRELIMINARY RECOMMENDATION

Description

Based on a preliminary assessment, it is suggested to continue investigating the use of the inside shoulder during peak hour, high traffic volume periods, as well as during roadwork, events, or incidents. The initial strategy involves extending the inside dynamic shoulder lane for the extent of the study corridor from approximately Torrence Avenue to near the I-65 interchange in the eastbound direction and from the I-65 Interchange to Torrence Avenue in the westbound direction.

Currently, trucks are restricted to only use the right two lanes. Field observations indicate that tucks frequently use the right three lanes and occasionally utilize all four lanes. With this dynamic shoulder lane deployment, it is suggested that additional signage and DMS be implemented to reinforce the requirement for the trucks to only use the right two lanes of the highway and to restrict use by trucks of the left lanes and the inside median shoulder lane.

The inside shoulder posted speed may need to be reduced due to the reduced lane width. Initial agreement has been reached with INDOT, FHWA and the project team that the inside shoulder lane will be signed with a design speed of 50 MPH. Based on preliminary calculations with respect to the horizontal alignment, the inside shoulder lane will meet horizontal stopping sight distanced at the reduced design speed. It is also possible that the mainline speed limit may need to be reduced when the inside shoulder is opened for traffic. This potential posted speed related operations strategy will be resolved when a more detailed analysis is complete.

Outside shoulder use is being proposed only during heavy congestion periods as a result of significant lane closures due to maintenance, events, or incidents. Under this strategy, the right shoulder would only be opened at the location of the event and remain closed throughout the rest of the corridor. As a result, any particular section of the outside shoulder would only be used on rare occasions. Expected use of any section of the shoulder would likely be less than 5% of the time.

Permitted speeds on the outside shoulder lane would be limited based on the final design details, but based on preliminary investigations, the suggested operating speeds would be less than 25 MPH. This lower posted speed implies that the outside shoulder lane would only be utilized when the mainline speeds are operating at 30 MPH or less.

Refer to Appendix A for full width typical sections for 10 feet and 11 feet dynamic shoulder lane alternatives.

The existing shoulder pavement is plain jointed concrete. Pavement cores will be needed for final design but according to the existing plans, the existing pavement in generally 15" of PCCP on 9" of compacted aggregate subbase on subgrade treatment.

The design of the dynamic shoulder lane should provide for the monitoring of the mainline traffic conditions to assist in determining when the shoulder lane should open or closed. The monitoring system should provide support to the TMC staff to quickly determine if the shoulder is clear of traffic and debris prior to opening. The system should also allow for the inside shoulder to be opened during roadwork and incidents as needed to improve traffic flow. Operations to open and close the shoulder lanes should be permitted from either the local TMC, or the Indianapolis TMC.

The system should include adequate detection and monitoring capabilities to ensure that the outside shoulder is only opened when and where speeds are significantly reduced and to quickly close the outside shoulder lane again when traffic flow improves. In addition, the strategy must provide for roadway DMS signing at appropriate intervals to allow for only the applicable section of the shoulder to be opened as needed.

The efficient use of the shoulders for hard shoulder running will rely on the ability to provide lane control and variable speed limits as described in the subsections to follow.

Planning, or high level cost estimates for the dynamic shoulder lane strategy are summarized in Table 4.

Table 4: High Level Costs – Dynamic Shoulder Lanes

ITEM	UNIT COST	QUANTITY	TOTAL
RECOMMENDED CIVIL MITIGATION	$6,180,000	1	$6,180,000
GANTRY STRUCTURES AND FOUNDATIONS	$220,000	46	$10,120,000
GANTRY EQUIPMENT/CABLING INSTALLATION, INTEGRATION, TESTING	$34,604	46	$1,591,784
LANE CONTROL SIGNS	$133,000	46	$6,118,000
SMALL MOUNTED DMS ON GANTRY ENDS (roughly 6'x8') 2 per gantry	$56,000	15	$840,000
GANTRY MOUNTED CCTV CAMERAS	$8,000	46	$368,000
CABINETS, HANDHOLES, POWER SERVICE, COMMUNICATIONS	$61,750	46	$2,840,500
CENTRAL ATM SOFTWARE	$350,000	1	$350,000
COMMUNICATIONS REDUNDANCY AND PROTECTION OF EXISTING EQUIPMENT	$7,000	50	$350,000
	TOTAL:		$28,758,284

The recommended civil mitigation measures shown in the cost table above are described further below, along with optional mitigation measures. The items below do not account for contingency and lump sum items such as Maintenance of Traffic (MOT), construction engineering, etc. Those items will be summarized in the full consolidated cost estimates included in Appendix B.

Recommended Mitigation Measures:

Pavement Replacement, Inside shoulder for super correction: $2.8 Million

Notes: The inside shoulder will be utilized by motorists at higher speeds and this line item will involve reconstructing the pavement such that the shoulder slopes in the same plane as the lanes. This measure will reconstruct the inside shoulder at three locations (assumed each curve to be 2500 feet but will need to be confirmed with survey during final design). According to the existing plans, when the inside shoulder is on the high side of the curve, the shoulder is sloped in the opposite direction of the superelevation. Reconstruction of the pavement will result in need to reconstruct the median barrier to a bifurcated median barrier.

Shoulder Joint Repair, Inside Shoulder: $800,000

Notes: It is assumed that 10% of the existing transverse and longitudinal joints will need to be repaired for safety and rideability.

Shoulder Joint Repair, Outside Shoulder: $760,000

Notes: It is assumed that 10% of the existing transverse and longitudinal joints will need to be repaired for safety and rideability.

Drainage inlet improvements, Inside Shoulder: $1.5 Million

Notes: There are numerous “H” inlets, equipped with the “X” formation slotted drains. The slotted drains should have been designed to handle vehicle loads, but these inlets were not designed to be driven on continuously. This mitigation measure is “recommended” to remove the slotted drain and patch the concrete to improve rideability, driver comfort, and potentially as a safety feature because vehicles could rupture a tire on the slotted drain. However, this mitigation measure could also be considered optional as the slotted drains should be rated to manage live traffic.

Emergency Turn around Gates, Inside Shoulder: $320,000

Notes: Given that one of the key concerns from operations staff is maintaining quick access to incidents with the potential use of shoulders as travel lanes, INDOT Maintenance has proposed emergency vehicle turn around gates be placed between each interchange (8) in the median. These gates will help with accessing incidents quickly and clearing the roadway sooner.

Figure 17: Turn Around Gate Example

Optional Mitigation Measures:

Drainage Improvements, Inside Shoulder: $14 Million

Notes: Significant drainage improvements will need to occur to meet current hydraulic and spread criteria as the existing shoulder will be greatly reduced to accommodate an inside shoulder lane. It is anticipated that a large number of proposed inlets will need to be installed, the existing pavement will need to be removed to connect the proposed system, median barrier removed and replaced to construct the proposed system, and additional outlets will need to be jacked and bored. This mitigation measure is optional because the dynamic shoulder lanes can be closed during rain and snow events, in which case the drainage improvements would not be required.

Drainage Improvements, Outside Shoulder: $5 Million

Notes: Significant drainage improvements will need to occur to meet current hydraulic and spread criteria as the existing shoulder will be greatly reduced to accommodate an outside shoulder lane. However, the outside shoulder lane is only anticipated for incident management and maintenance management. Vehicles will be utilizing the outside shoulder lane infrequently and traveling at much slower speeds. The outside shoulder lane can be closed during rain and snow events to eliminate the need for drainage improvements.

Retrofit load transfer bars, Inside Shoulder: $12.4 Million

Notes: It does not appear that existing retrofit load transfer bars were used in construction of the inside and outside shoulders. The inside shoulder riding lane will be signed to restricted trucks and it is anticipated trucks will avoid using the shoulder lane, therefore, the load transfer bars are considered optional.

Retrofit load transfer bars, Outside Shoulder: $4.7 Million

Notes: It does not appear that existing retrofit load transfer bars were used in construction of the inside and outside shoulders. Although the outside shoulder lane will be signed to restricted trucks, it is highly likely that trucks will use the outside shoulder lane (which will be used during incident management). The $4.7M cost assumes that proposed retrofit load transfer bars be placed in the anticipated wheel path (not entire shoulder width) over approximately 80% of the project length (in Indiana only) to accommodate use of the outside shoulder lane. In the spring of 2021, it was observed in the field that INDOT is placing traffic on the outside shoulder during maintenance of traffic for road construction. If the outside shoulder withstands the traffic through completion of this current work, this measure could be considered optional.

ITEMS THAT NEED FURTHER INVESTIGATION AND OR RESOLUTION

- The need for retrofit load transfer bars is being coordinated with INDOT LaPorte and Central office pavement design.
- The MOT scheme currently in place (spring of 2021) with placing traffic on the outside shoulder could have an impact on the decision to place, or not to place, retrofit tie bars in the outside shoulder. Additional investigation will need to occur when this traffic scheme is completed.
- The exact limits will need to be determined with respect to where the shoulder will need to be rebuilt to address inappropriate super-elevations.
- Identify the exact locations for lane control signs to support outside shoulder lane usage.
- Locations for all structure posts that will be placed in the median will need to be investigated with respect to maintaining an adequate cross-section.
- The project team will need approval for preferred worst-case cross sections. A design exception will be required if a 10 foot inside or outside shoulder lane is preferred.
- Topographic survey was not available at the time of preparing this report and specifically in generating the proposed typical sections included in Appendix A. Information to formulate assumptions and proposed alternatives were derived from aerial photos and existing plans. All cross slopes, widths, and materials will need to be confirmed with survey when made available.

Lane Control

Dynamic Lane Use Control: This strategy involves dynamically closing or opening individual traffic lanes as warranted and providing advance warning of the closure(s) (through the use of Lane-Use Control Signals), in order to safely merge traffic into the adjacent lanes. In an ATDM approach, as the network is continuously monitored, real-time incident and congestion data is used to control the lane use signals ahead of the lane closure(s) and dynamically manage the location to reduce rear-end and other secondary crashes.

This strategy is an integral part of the suggested Dynamic Shoulder Lane strategy described earlier and would be used to advise drivers that the shoulder lanes are open or closed. In addition, this strategy would allow for the opening and closing of all the lanes to support needed maintenance and incident management.

CORRIDOR SPECIFIC DETAILS

The use of lane control should be applicable throughout the corridor in both directions. The following sections identify corridor specific operational and infrastructure considerations as well as related issues.

Operational Considerations

One of the key considerations that was identified by many stakeholders was the importance in being able to maintain the roadway. Vehicle and truck traffic can be significant throughout the day. Snow removal, roadway maintenance, drainage maintenance and the removal of debris were all mentioned as key considerations.

It was also indicated that the ability to respond to, and quickly and safely clear incidents in the corridor, is a very important consideration. Several stakeholders indicated that a good portion of the congestion in the corridor is the result of incidents or maintenance activity in the corridor. In performing field reviews of the freeway and study area, it was noted that there is a significant amount of debris located within the shoulders throughout the corridor.

Lane control will support safe and efficient roadway maintenance, while also aiding in the improvement of traffic flow along the study corridor. However, it is also understood that the lane control gantries will also require maintenance.

Use of a lane control system to manage incidents could be assessed in the traffic operations model (micro-simulation), where alternative traffic management scenarios can be analyzed, and potential benefits quantified. For improved performance, these traffic management scenarios could incorporate the use of the inside or outside shoulders to provide temporary capacity around an incident location.

Physical Infrastructure Considerations

As indicated previously, the majority of the study corridor consists of four to five lanes with inside and outside shoulders that vary in width between 10 feet and 14 feet. There are several full span sign gantries located over both directions of the travel lanes to support directional signing and lane assignment signs for the exit lanes. The existing sign gantries are all truss type structures without walkways for maintenance.

Understanding that ideal gantry placement for lane control would allow for motorists to see the next lane control gantry (signals) as they pass under the previous gantry, the placement of new lane control gantries will need to be coordinated closely with the location of the existing sign gantries. In some cases, there may be a need to combine the fixed signing from a current gantry with the new DMS gantry for the lane control signs.

The placement of gantry posts in the median will increase the width of the median barrier, typically expanding the width of the barrier by an additional 12 inches in each direction and as a result, potentially restricting the available cross section for other TSMO strategies. In addition, the outside shoulder is frequently adjacent to a sound wall. The outside post for any new gantry may require the rebuilding of the sound wall at that area to allow for placement of the outside gantry post and foundation.

Through the various meetings, INDOT has indicated that they plan to rebuild the structural section of the freeway in 2035 to 2040. At that time, there is a desire to rebuild the roadway with full 12-foot lanes - where practical. In light of this future construction, INDOT would prefer that any new gantry implemented as part of this strategy is designed such that they will not need to be replaced when the structural section is rebuilt. This requirement means that the outside posts for any new gantry may need to be constructed outside the face of the sound walls in many locations. Construction beyond the sound walls may also require a minimal amount of additional right of way at some outside gantry post locations.

Understanding that the corridor crosses state lines, it is anticipated that there will be full width gantries in Indiana and Illinois. Ideally, a common gantry type will be deployed in both states, however approval from both states will be required.

Lane control signing is expected to be one part of a combined TSMO strategy that is likely to include Dynamic Shoulder Lanes, Variable Speed Limits, Queue Warning and other enhanced ITS strategies. As a result, the lane control gantries will need to support multiple DMS and possibly fixed / static signing.

PRELIMINARY RECOMMENDATION

Description

Given the potential for inside and outside lane control for the Dynamic Shoulder Lane and the heavy focus on the need for safe and efficient roadway maintenance, while maintaining maximum traffic flow, the use of full width gantry lane control appears to be appropriate throughout the study corridor. Lane control should allow for the closing and opening of all the mainline travel lanes as well as the inside and outside shoulders as required for the recommended Dynamic Shoulder Lane strategy.

The operating system should provide for full remote control from the regional TMC and the Indianapolis TMC. The system should provide for control of all lane control gantries in Indiana and Illinois. The system should also allow for advanced warning for lane closures and the smooth transitioning of vehicle speeds when approaching the closed lanes. The following diagram, Figure 18, shows sample lane control and variable speed limit (VSL) signing that is in use on a similar corridor.

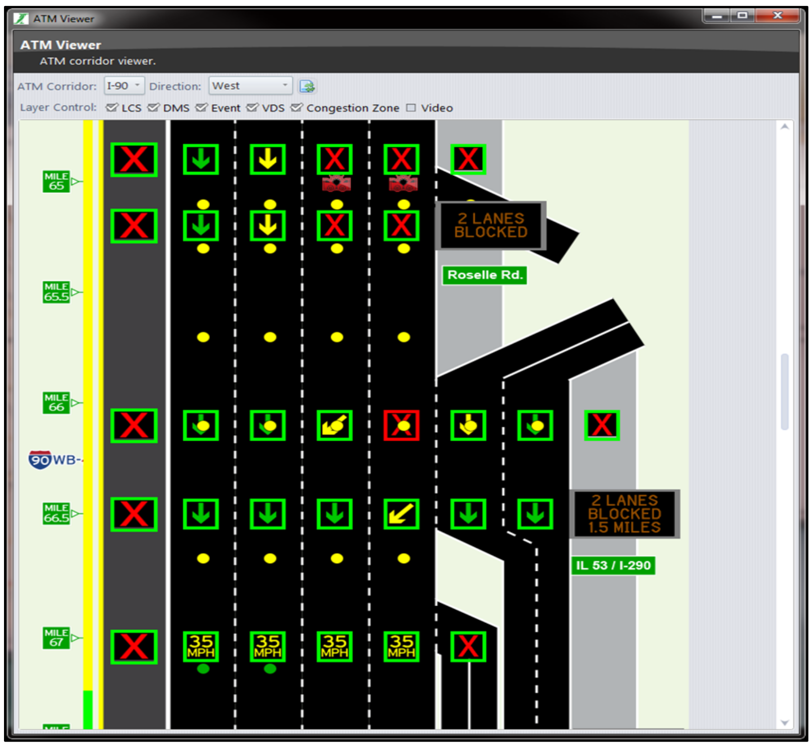


Figure 18: Sample Combined LC/VSL Signing Schematic (Illinois Tollway ATM Design)

The diagram depicted in Figure 18 represents a schematic layout of a combined Lane Control and VSL signing scheme for a two-lane closure, and specifically only in the area of the closure in the two right lanes. Additional queue warning and VSL step down speeds would be included in advance of what is shown in this schematic diagram. This figure shows the potential lane control signing when a single DMS is used per lane, with the DMS used for either Lane Control or VSL. Alternatively, each lane could have VSL and lane control signing. The suggested signing scheme, and gantry DMS signing configuration for the study corridor will be addressed along with the detailed design.

Preliminary approximate locations for lane control gantries along the study corridor are shown below in Figure 19.

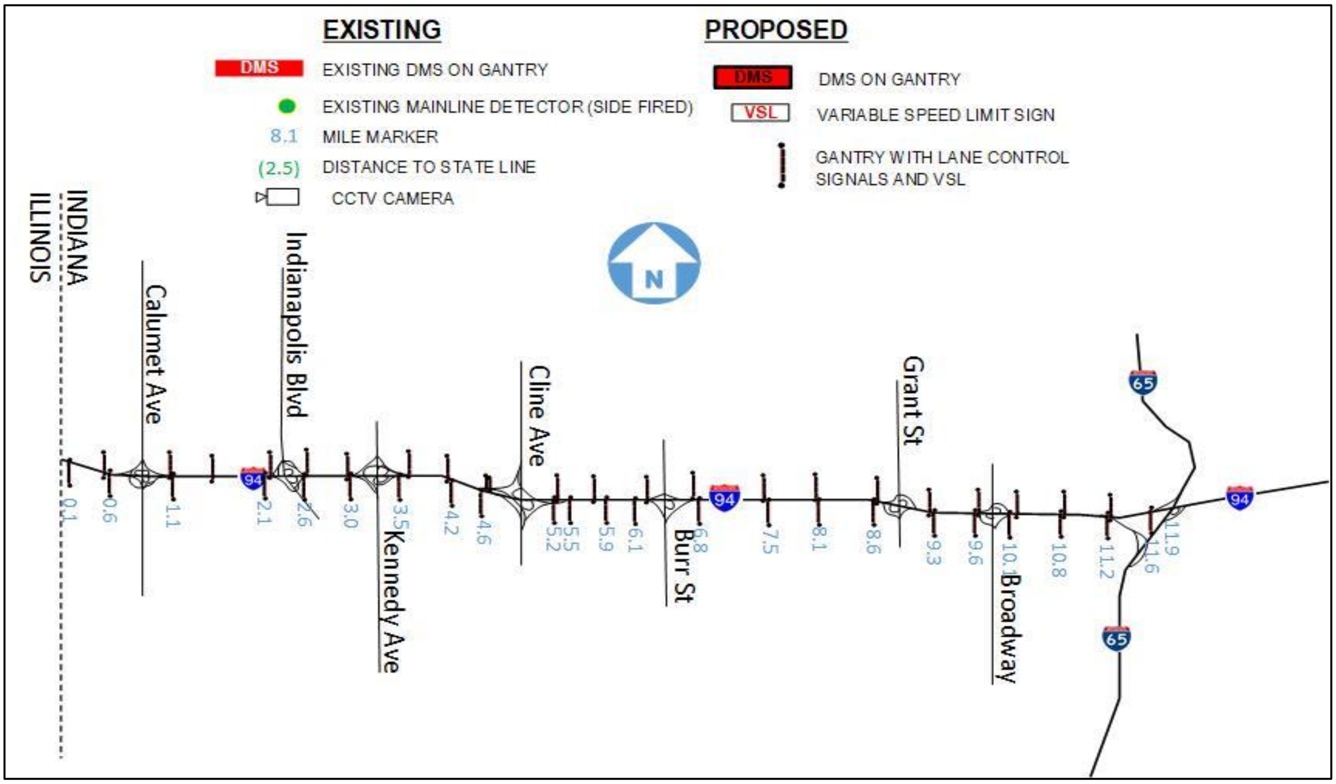


Figure 19: Preliminary Gantry Locations

Ideally, lane control gantries should be placed at roughly half mile spacing such that motorists can see the next gantry as they pass under the previous gantry. Consideration will be given to separating the new lane control gantries from existing static sign gantries to eliminate visual clutter or confusion. At one location, use of an existing truss (mile post 10.6 as shown in Figure 20) is recommended to achieve the designed gantry spacing and separation from other signs. Based on an initial assessment, it appears that there is only one sign on this truss sign gantry, and this sign could potentially be relocated to a new cantilever structure.

Figure 20: Existing Sign Truss at Exit 10/Broadway

On the Illinois side, there may be three new lane control gantries placed at half mile intervals approaching the Indiana border in the eastbound direction. These new gantry locations are shown below in Figure 21 along with existing and proposed DMS locations.

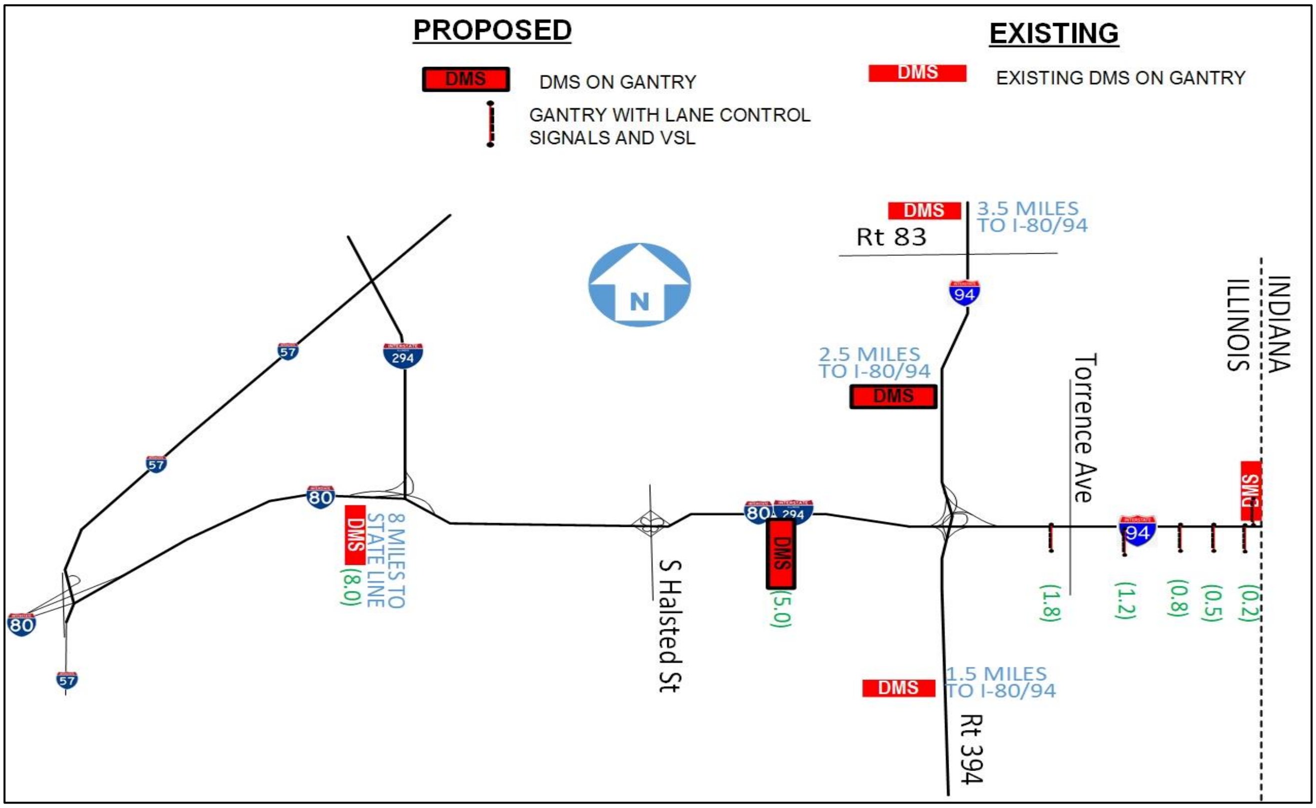


Figure 21: Preliminary Gantry Locations in Illinois

Based on the initial investigations, the existing DMS on I-94 and I-80 should be supplemented by two new DMS locations placed where they can provide relevant information to motorists as they approach the lane control signals. The existing DMS on IL 394, south of I-94, is located in an appropriate area to be used for the purpose of providing advance information to approaching motorists.

HIGH LEVEL COSTS

The costs for lane control are included in the dynamic shoulder lane strategy described earlier. However, two additional mainline gantry DMS have been identified as being required in Illinois to support the lane control strategy at a total cost of $670,000.

ITEMS THAT NEED FURTHER INVESTIGATION AND OR RESOLUTION

- Gantry structure type: Truss structure versus tube structure.
- Exact location for new lane control gantries.
- Specific gantry design details.
- Approach for combining Lane Control, VSL and queue warning messages, as well as possible fixed / static signing. Options include:
  - Shared DMS for Lane control and VSL messages, so the sign only displays one or the other.
  - Separate DMS (or DMS space) to support both lane control and VSL signing at the same time.
- DMS sizing and specifications.
- Multiple positions may require minimal right-of-way acquisition for the outside post of the new gantries.

Variable Speed Limits (VSL)

This strategy adjusts speed limits based on real-time traffic conditions, roadway incidents, events, work zones and/or weather conditions. Dynamic speed limits can either be enforceable (regulatory) speed limits or recommended speed advisories, and they can be applied to an entire roadway segment or individual lanes. Of the 19 VSL systems deployed in the US, 13 are regulatory and six are advisory. In an ATDM approach, real-time and anticipated (or predicted) traffic conditions are used to adjust the speed limits dynamically to meet agency goals/objectives for safety, mobility, or environmental impacts.

Variable speed limit systems used for congestion-based Active Traffic Management (ATM) are sometimes referred to as “speed harmonization systems.” The purpose of speed harmonization is to dynamically and automatically reduce speed limits within or before areas of congestion, accidents, or special events to maintain flow and reduce the risk of collisions due to speed differentials. The displayed speed limits for VSL systems used for congestion are generally updated every 30 seconds to 15 minutes. An interval of ranging between one and five minutes was found to be the most common practice. With respect to sign placement, typically, variable speed limit signs are placed at intervals of a half mile (0.5 miles) to a mile (1.0 miles) and speed step downs from sign to sign are either in 5 MPH or 10 MPH increments. These variable speed limit systems are commonly used in conjunction with other ATM strategies such as queue warning and dynamic shoulder lanes.

CORRIDOR SPECIFIC DETAILS

Operational Considerations

A key consideration in the implementation of a variable speed solution in the corridor is that Indiana has legislation to allow for regulatory VSL and Illinois does not have legislation for regulatory VSL. With the project limits crossing the state border, the solution will need to support advisory speeds in Illinois and regulatory speed limits in Indiana, or simply provide advisory speeds in both states. However, experiences through past deployments indicate that regulatory VSL provides better results (driver compliance) and is preferred.

A key part of the value to providing VSL is the gradual stepping down of the speed from the normal posted speed limit to the desired speed limit. Given the limited length of the corridor, it is operationally preferred to start the VSL step down prior to the start of the logical project limits. Assuming a 10 MPH step down and approximately half mile sign spacing, the suggested start point for the VSL signing is approximately two miles (2.0 miles) prior to the project logical termini. This start location would make full use of the VSL functionality throughout the study corridor, between the Torrence Avenue and I-65 interchanges.

As indicated in the previous sections, the speed limit on the dynamic shoulder lanes (in Indiana) will likely be posted at 5 MPH slower than the mainline lanes. As a result, the VSL signing in the dynamic shoulder lane section of the study corridor will need to support the signing of differential speed limits between the mainline lanes and the dynamic shoulder lanes. Noting that the dynamic shoulder lane speeds may be limited, particularly on the outside shoulders, stepping down the mainline speeds prior to the start of the dynamic shoulder lanes would be required and represents another reason to extend the VSL further upstream of the initial study limits.

Consideration will need to be given to the simultaneous signing of Lane Control, Dynamic Shoulder Lanes, Variable Speed Limits, and Queue Warning in the corridor.

Analysis of the application of variable speed limits can be conducted using the corridor traffic operations model (micro-simulation). The traffic operations model is sensitive to travel speeds and the potential to optimize traffic throughput by adjusting travel speeds that may increase density while avoiding unstable flow conditions. Therefore, through the use of targeted performance measures, the potential benefits of a variable speed system can be quantified.

Physical Infrastructure Considerations

- As indicated under the Operational Considerations, the limited length of the initial study corridor must be considered in the VSL design.
- With four to five lanes in each direction throughout the study corridor, and the presence of heavy truck traffic, special consideration will need to be given to the placing of the VSL signs to ensure adequate sight distance.
- Full width gantries are expected for Lane Control, so these same gantries are also likely to be able to accommodate the VSL signing.
- The current microwave based vehicle detection in the corridor is old and several, if not all the locations, may need to be updated or replaced.

PRELIMINARY RECOMMENDATION

Description

It is recommended that VSL is implemented throughout the study corridor in both directions. Messaging for the VSL system should start approximately two to three miles prior to the study corridor termini limits so that speeds can be stepped down prior to the start of the dynamic shoulder lane section (when needed) to make the maximum use of the TSMO strategies within the project limits.

The three mile advance signing translates to six stand-alone variable speed signs on both ends of the study corridor for the purpose of stepping down speeds as motorists approach the gantries. These signs would be installed on both vertical members or posts of existing gantries, or on new structures where existing gantries do not exist. These advance signs will typically consist of a static speed advisory sign with a dynamic insert like the examples shown below in Figure 22. Since variable speed limits currently cannot be enforced in Illinois, advisory signs would be used on the Illinois side, while regulatory signs would be used on the Indiana side.

Figure 22: Examples of Advisory and Regulatory Speed Limit Signs

An integrated system is recommended to support Variable Speed Limits, Dynamic Shoulder Lanes, Lane Control, and Queue Warning for the entire project area. As such, VSL signs will be installed on new gantries except for standalone VSL signs that are installed in advance of the project limits as shown below in Figure 23 and Figure 24.

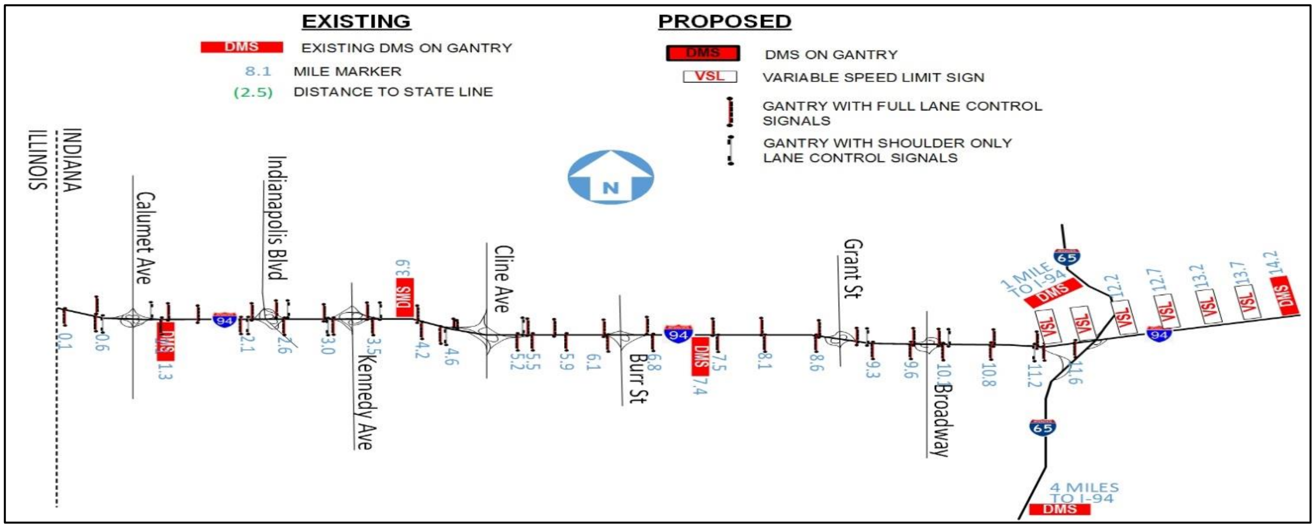


Figure 23: Preliminary VSL, HSR, LC and Queue Warning Locations

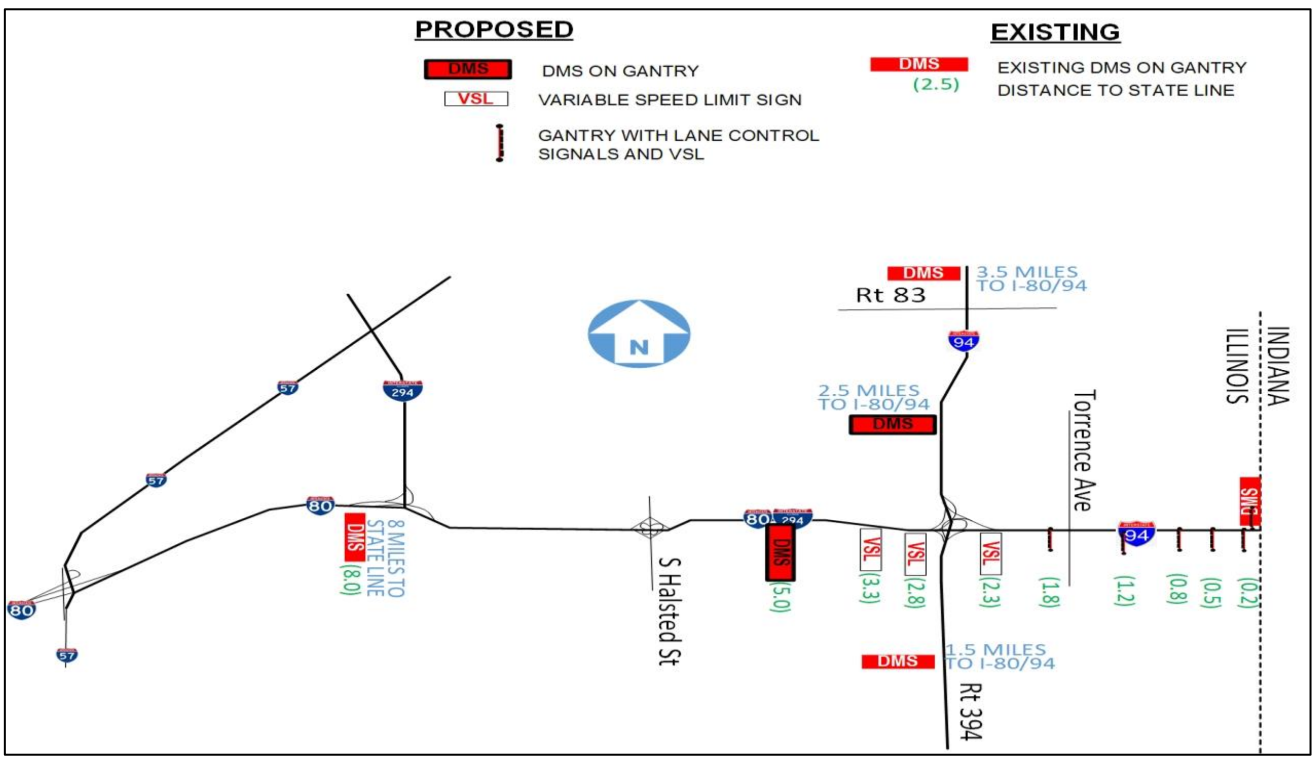


Figure 24: Integrated VSL, HSR, LC and Queue Warning Locations in Illinois

Measuring traffic speeds in the immediate vicinity of each gantry is a critical element of the effective operation of the variable speed limit system. Although there are existing speed detectors within the study corridor, it is likely that these existing detectors will need to be replaced either due to the age of the detectors or for consistency purposes. Noting that each lane control gantry should have corresponding vehicle detection in each lane, new vehicle / speed detectors are needed at every gantry location.

The gantries may have a single display over each lane providing both lane control and variable speed limit graphics simultaneously, two smaller DMS, or a single smaller DMS that can only display one strategy at a time (VSL or lane control). The exact DMS display details will be addressed as part of the final Concept of Operations and detailed design. Preliminary suggestions for the DMS would include a display that would be approximately four feet wide by six feet tall per lane and be able to display VSL and lane control at the same time.

An additional slightly larger display will be added to the end of select gantries, near the outside shoulder, to provide additional information relating to queues or other relevant conditions. A few examples of a small DMS display flanking VSL signs are shown below in Figure 25.

Figure 25: VSL and Small DMS Sign Examples

The potential locations for the small informational DMS are shown below in Figure 26. The initial assumption used in determining these locations is that every third gantry would have the additional informational DMS on the right side unless there is an existing full size DMS nearby. Any existing full size DMS in the study limits should become accessible through the ATM module to display supporting VSL and lane control messaging as shown above.

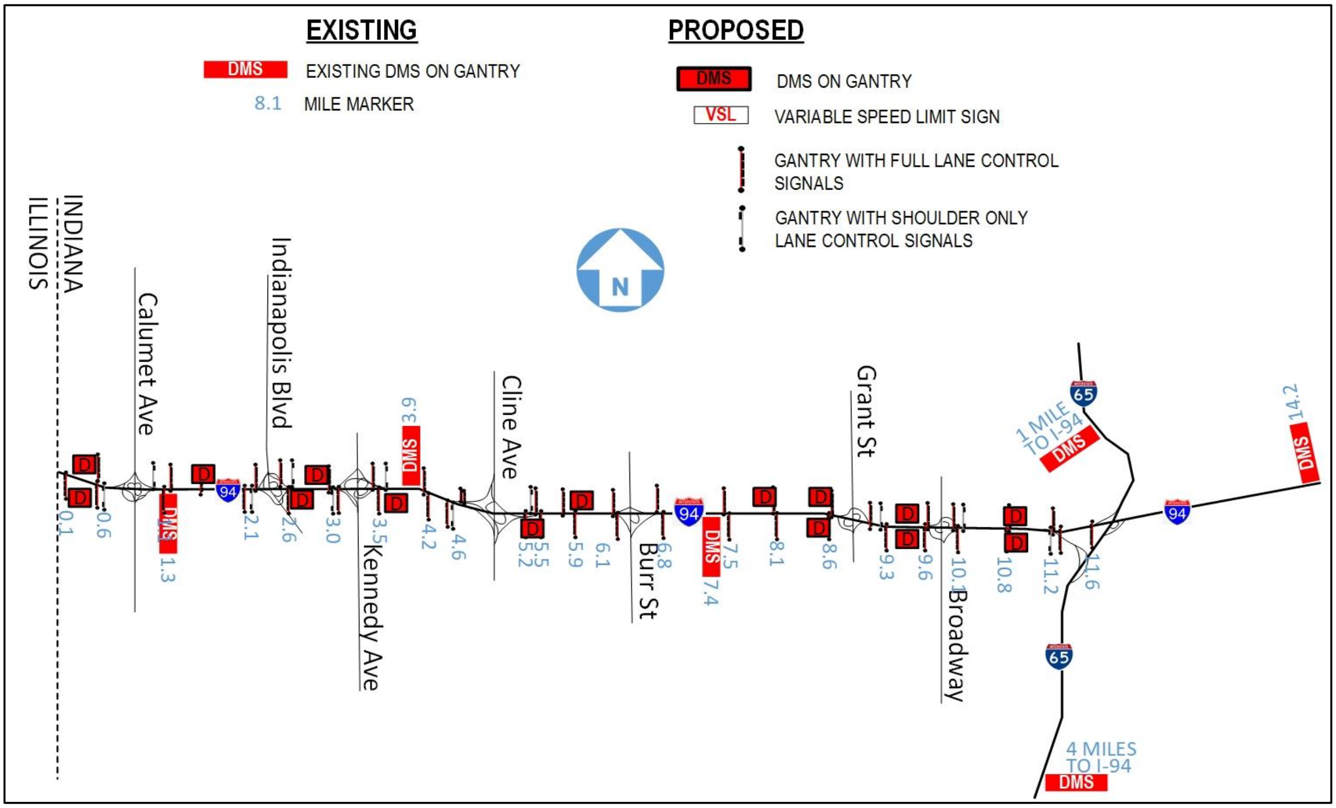


Figure 26: Potential Locations for Informational DMS

These small DMS will supplement the existing DMS in the corridor, with placement such that there is at least one DMS between each interchange within the study corridor.

Typically, dedicated CCTV cameras are also installed on every gantry, with two cameras providing full coverage of the inside and outside shoulder. This approach, which is suggested for the study corridor, will enable operators to efficiently review and confirm the conditions on the inside and outside shoulder, which will allow the dynamic shoulder lanes to be opened quickly when needed. The goal is to provide full coverage of both shoulders without concern for occlusion or the need to Pan / Tilt / Zoom (PTZ) the cameras to see the entire length of the study corridor.

Planning or high level cost estimates have been prepared for the VSL system and these are summarized below in Table 5.

Table 5: High Level Costs – Variable Speed Limit System

ITEM	UNIT COST	QUANTITY	TOTAL
VARIABLE SPEED LIMIT SIGNS	$38,000	52	$1,976,000
MICROWAVE RADAR DETECTOR	$3,500	52	$182,000
CABINETS, HANDHOLES, POWER SERVICE, COMMUNICATIONS	$62,614	52	$3,255,928
	TOTAL:		$5,413,928

Key assumptions related to the high level cost estimates include:

- Variable speed limit signs will likely be mounted on existing gantries or on the proposed gantries that are included with the dynamic shoulder lane and lane control strategies, so new structures are not included in these costs. If VSL is chosen as a standalone strategy without dynamic shoulder lanes and lane control, additional costs will likely be incurred for gantry or related structures.
- These costs do not include mobilization/demobilization and maintenance and protection of traffic. These related costs are included in the consolidated cost estimate in Appendix B.

ITEMS THAT NEED FURTHER INVESTIGATION AND OR RESOLUTION

- Exact VSL signing locations and design, particularly for the advance VSL located before the gantries.
- Gantry DMS VSL signing details.
- Signing details related to Illinois advisory and Indiana regulatory VSL.
- Confirm step down speed intervals.
- Many operational and enforcement details.

Queue Warning

This strategy involves real-time displays of warning messages (typically on dynamic message signs and possibly coupled with flashing lights) along a roadway to alert motorists that queues or significant slowdowns are ahead. By providing the advance warning, reductions in rear-end type crashes and improved safety are anticipated. In an ATDM approach, where the traffic conditions are monitored continuously, the warning messages are dynamic based on the location and severity of the queues and areas experiencing reduced speeds (slowdowns). Queue warning is frequently deployed in coordination with variable speed limit systems.

CORRIDOR SPECIFIC DETAILS

Operational Considerations

Within the study corridor, queues can propagate from any location. Frequently, these queues will start from an event in the roadway, such as a stalled vehicle, accident, or just debris. With the high traffic volumes experienced in the corridor, these queues can grow quickly when there is a significant lane blockage. Understanding that the queues can start anywhere, and the end of the queue is likely to move over time, the strategy needs to allow for automated traffic monitoring and adjustments to the queue warning messaging.

When a significant incident occurs, queues can extend for miles, starting within the study corridor and propagating back to well before the study corridor. Ideally these queues will be managed within the corridor and if they extend beyond the study limits, INDOT, IDOT, ISHTA, Skyway and the Indiana Toll Road all have their own ATMS to manage the queues on the connecting freeway network. Timely, accurate and efficient display of queue warning messaging will require near real time sharing of traffic and queue information between agencies, as well as a coordinated operational response between the agencies.

Considering that a significant amount of the queues that originate within the corridor are related to a roadway event, queue warning messaging will need to be coordinated with event signing, dynamic shoulder lanes, lane control, and variable speed limit strategies.

Analysis of the type and location of collisions occurring along the study corridor can provide an indication of the potential benefits (e.g., reduction in secondary collisions) that could be attributed to a queue warning system, by providing advance notice to approaching drivers of congested conditions and the need to reduce speed or even stop.

Physical Infrastructure Considerations

There are no specific roadway geometric issues in the study corridor that require special queue warning messaging. However, the ITS infrastructure and communication network between INDOT, IDOT, ISTHA and the Indiana Toll Road will be important in providing a seamless integrated solution that can provide appropriate queue warning to motorists using the study corridor.

Currently, INDOT, IDOT, ISTHA and ITR are not physically connected via a fiber network and each agency operates their own ATMS. However, information is shared between agencies via the Lake Michigan Interstate Gateway Alliance (LMIGA). LMIGA is a voluntary organization with active member participation from the Wisconsin Department of Transportation, the Illinois Department of Transportation, the Indiana Department of Transportation, the Michigan Department of Transportation, the Illinois Tollway, the Skyway Concession Company LLC, and the Indiana Toll Road Concession Company LLC. The goal of LMIGA is to focus on operations within the region to ensure that traffic moves safely and efficiently. This goal is realized by interagency communication and coordination, improvement projects, training efforts, and region wide planning.

The LMIGA ITS Priority Corridor Program operates through a comprehensive structure of working groups that meet on a regular basis. LMIGA regional travel information, including current travel time, congestion, incident, construction, special event, and weather information is available on the Travel Midwest web site.

PRELIMINARY RECOMMENDATION

Description

A connected and integrated system will provide the best response for queue warning and many of the other TSMO strategies being considered. Queue and event information should be available to all the agencies in near real time. This information can be in the form of an integrated single system for the region or interfaces between agency systems. Given that events in this area can cause backups well beyond the study corridor limits, it is likely that queue management will best be served through near real time system interfaces between the agencies.

The detection within the study corridor limits should be adequate to provide reasonably accurate end of queue information. When queues extend beyond the study corridor limits, the responsible agency will need to monitor queue lengths.

The agencies should develop coordinated response plans to ensure consistent responses and messaging throughout the region.

Considering the close proximity of the INDOT and IDOT communications fiber, it seems appropriate that the two fiber networks should be connected as part of this or any other significant TSMO strategy implementation, with appropriate firewalls and security considerations to protect both networks.

Planning or high level cost estimates have been prepared for a proposed queue warning system and these are summarized below in Table 6.

Table 6: High Level Costs – Queue Warning System

ITEM	UNIT COST	QUANTITY	TOTAL
SMALL MOUNTED DMS ON GANTRY ENDS (roughly 6'x8') 2 per gantry	$56,000	15	$840,000
QUEUE WARNING SOFTWARE	$250,000	1	$250,000
CENTER TO CENTER INTEGRATION	$200,000	1	$200,000
	TOTAL:		$940,000

Note: These costs do not include mobilization/demobilization and maintenance and protection of traffic. These related costs are included in the consolidated cost estimate in Appendix B.

ITEMS THAT NEED FURTHER INVESTIGATION AND OR RESOLUTION

- Details need discussed and agreed upon with the agencies as to how to connect the existing and proposed systems as well as the message sets that need to be passed between these systems. This communications interface may be through the Gateway system or directly between agency ATMS.
- Operational response and messaging agreements should be developed.
- Direct fiber connection details, including physical hardware, firewalls and security protocols will need to be developed.

Ramp Metering

Ramp meters are traffic signals installed on freeway on-ramps to control the frequency at which vehicles enter the flow of traffic on the freeway. Vehicles traveling from an adjacent arterial roadway onto the ramp typically form a queue behind the stop line; the extent of the queuing is dependent upon the traffic demand. The vehicles are then individually released onto the mainline, often at a rate that is dependent on the mainline traffic volume and speed at that time.

In addition to breaking up platoons, ramp meters help manage entrance traffic demand at a level that is near the capacity of the freeway, which can help slow or prevent traffic flow breakdowns along the mainline lanes. Ramp meters are shown to reduce peak hour occupancies and quicken recovery from mainline breakdown back to or below the critical occupancy threshold. Typical results include reductions in travel time, reductions in crash rates, and increased traffic speed.[iv]

Adaptive Ramp Metering consists of deploying traffic signal(s) on ramps to dynamically control the rate vehicles enter a freeway facility. This in essence smooths the flow of traffic onto the mainline, allowing efficient use of existing freeway capacity. Adaptive ramp metering utilizes traffic responsive or adaptive algorithms (as opposed to pre-timed or fixed time rates) that can optimize either local or system-wide conditions. Adaptive ramp metering can also utilize advanced metering technologies such as dynamic bottleneck identification, automated incident detection, and integration with adjacent arterial traffic signal operations. In an ATDM approach, real-time and anticipated (predicted) traffic volumes on the freeway facility would be used to control the rate of vehicles entering the freeway facility. Based on the traffic conditions along the freeway, the ramp meter rates will be adjusted dynamically.

CORRIDOR SPECIFIC DETAILS

Operational Considerations

There is currently ramp metering in operation in Illinois on IDOT freeways within the Chicago Metro area. In addition, INDOT is investigation ramp metering in the Indianapolis area and may expand ramp metering throughout the state. From a motorist’s perspective, it is helpful to ensure that the ramp metering approach appears consistent throughout the area.

With the potential for the use of dynamic shoulder lanes on the outside shoulder, the ability to break up platoons with ramp metering will be beneficial. However, at the same time, if cars using the outside shoulder prior to the on-ramp are allowed to continue though the on-ramp gore area, the acceleration distance from the ramp meter will be greatly reduced. Special consideration will need to be given to any outside shoulder speed limits and the need for ramp metering acceleration distances to match the outside shoulder speeds. In addition, the design of the outside shoulder lane will need to address potential usage that allows vehicles to travel over the gore area approaching the on ramp and the potential motorist confusion issues related to this unusual operational scenario.

There are several adaptive algorithm options available, however, it is likely that INDOT may prefer to use the same adaptive algorithm for all ramp metering corridors throughout the state.

INDOT currently uses the Q-Free MAXVIEW system for its traffic signal control. MAXTIME has a ramp metering control module with standard ramp metering functions. These ramp metering functions include start up and shut down functions, multiple lane metering, emergency vehicle preemption, time of day metering, local traffic responsive metering, and queue override and queue flushing strategies. The MAXVIEW ATMS also offers system interfaces with other software. Such interfaces could open up more advanced features for ramp metering in other areas such as to support corridor wide control and to address specific needs related to potential outside shoulder usage.

Ramp meters have a few basic elements that need to be considered when assessing their appropriateness for installation. Since ramp meters stop traffic and then let vehicles proceed, the need to provide queue storage is important. If during metering, vehicles queue along the ramp and the queue extends onto the adjacent arterial, this will cause additional congestion and lead to complaints from the adjacent municipalities. Also, since ramp meters stop vehicles, the ability to provide adequate acceleration distance for proper merging onto the freeway mainline is also important. As an initial assessment to confirm the appropriateness of ramp metering along the study corridor, a review of all on-ramps was conducted using Google Earth with respect to the distance available for queue storage and vehicle acceleration – as based on a reasonable ramp meter location given the existing geometry. Ideally, the ramp meter should be placed near the gore to maximize storage, provide roadside room for signal control infrastructure, and communications and mainline fiber run tie-ins, and provide adequate acceleration distance.

Ramp queue storage is most affected by on-ramp traffic demand volumes during peak periods and by the metering rate applied. Metering rates are commonly in the range of 4-15 cars per minute. For a single lane ramp, this means a ramp demand of approximately 900 vehicles per hour and for a two-lane ramp, approximately 1700 vehicles per hour. Through the application of the corridor traffic operations model, the ramp demands, and queuing needs will be evaluated within the model environment and then compared to the measured storage distances to determine where the potential for queuing problems might exist. As needed, two-lane metering can be modelled at these potentially problematic locations to see if queuing can be reduced and then compared to the ability to widen the on-ramp.

As noted above, the corridor traffic operations model will be employed to assess the potential improvement in traffic operations along the study corridor through the application of ramp meters. Applicable ramp metering algorithms will be coded in the traffic operations model to simulate the ramp metering rates at the selected on-ramps, and the changes in performance along the mainline lanes quantified through the use of appropriate metrics. The traffic operations model will also be able to estimate the extent of queuing on each metered ramp and the potential impacts to the upstream junctions, if any.

Physical Infrastructure Considerations

From the initial assessment, it was found that nearly all of the on-ramps in the study area merge onto the study corridor and remain an auxiliary lane until exiting at the next off-ramp. This ramp configuration removes the need to evaluate acceleration distances during normal operations, as these acceleration requirements should be met in nearly all locations (any exceptions are noted in the next section). However, the potential use of the outside shoulder during major events will need to be considered in the ramp metering strategy.

An individual on-ramp review is provided in the following section with diagrams indicating the available storage and acceleration distances and other general notes as appropriate.

INDIVIDUAL RAMP REVIEW

I-80/94 at Torrence Avenue

Torrence Avenue is the only arterial interchange on the Illinois side of the study corridor. In the westbound direction, the interchange is very close to the I-80, I-94, I-1294, IL 394 interchange, as depicted in Figure 27. There are additional freeway to freeway ramps that also merge with this westbound on ramp at this location. Due to the complexity and location of this westbound on ramp, ramp metering is not recommended in this direction.

Figure 27: Torrence Avenue at WB I-80/94

The eastbound direction is slightly better, as compared to the westbound on-ramp, in that there is a long distance to the next interchange and the road geometry is slightly less complex (see Figure 28). In summary, there is approximately 1500 feet of storage, of which approximately 400 feet is located along a two-lane segment. The eastbound on-ramp becomes an auxiliary lane when entering the freeway, therefore acceleration distance is not a factor. There is a frontage road ramp that also merges with this eastbound on-ramp approximately 750 feet past the proposed ramp meter location. Since the traffic volumes for this added ramp are expected to be very low, the added ramp should not pose a problem with respect to queuing. However, the selected ramp meter is located upon the structure within painted gore areas which may require barriers to protect the ramp meter infrastructure. Also, installing conduit runs may be expensive at this location.

Figure 28: Torrence Avenue at EB I-80/94

Based on these factors, ramp metering is not recommended at this location.

I-80/94 at Calumet Avenue

The Calumet Avenue interchange is a partial cloverleaf interchange, and the ramp metering was evaluated based on the information depicted in the diagrams in Figure 29 (eastbound) and Figure 30 (westbound).

The eastbound on-ramps merge together from the north and south directions of Calumet Avenue. There is excellent storage along the southbound on-ramp at approximately 2200 feet, but only moderate storage available along the northbound on-ramp at approximately 700 feet. The two ramps merge and can be metered together in staggered (alternating) two-lane metering and there is adequate acceleration / merge distance of approximately 1240 feet before the on-ramp lane becomes an auxiliary lane along the I-80/94 mainline.

The westbound on-ramps are separate ramps that merge together after the southbound on-ramp gore point. After they merge together, the two ramps form an auxiliary lane along the I-80/94 mainline. In the existing configuration, the two on-ramps would likely be metered separately with single-lane ramp meters. Both on-ramps have moderate to limited storage distances of approximately 700 feet and approximately 600 feet for the southbound and northbound on-ramps respectively. The northbound to westbound on-ramp has an acceleration issue as the merging traffic must weave with the westbound to southbound off-ramp traffic and merge onto the auxiliary lane. This on-ramp will require further investigation to potentially increase the acceleration distance.

Figure 29: EB Calumet Avenue at I-80/94

Figure 30: WB Calumet Avenue at I-80/94

I-80/94 at Indianapolis Boulevard

The Indianapolis Boulevard interchange is a modified cloverleaf interchange with additional loop type ramps. The ramp metering was evaluated based on the information depicted in the diagrams in Figure 31 (eastbound) and Figure 32 (westbound).

Figure 31: EB Indianapolis Boulevard at I-80/94

Figure 32: WB Indianapolis Boulevard at I-80/94

At this interchange, the eastbound on-ramps merge together from the north and south directions of Indianapolis Boulevard. There is reasonable storage of approximately 1440 feet available along the southbound on-ramp and also reasonable storage of approximately 1475 feet available along the northbound on-ramp. The two ramps merge and can be metered together in staggered (alternating) two-lane metering. There is adequate merging distance of approximately 1000 feet before the on-ramp lane becomes an auxiliary lane along the I-80/94 mainline.

The westbound on-ramps are separate ramps that merge after the southbound on-ramp gore point. After the two on-ramps merge, they form an auxiliary lane along the I-80/94 mainline. In the existing configuration, the two on-ramps would likely be metered separately with single-lane ramp meters. Both on-ramps have moderate storage distances of approximately 850 feet and approximately 825 feet for the southbound and northbound on-ramps respectively.

I-80/94 at Kennedy Avenue

The Kennedy Avenue interchange is a modified cloverleaf interchange. The ramp metering was evaluated based on the information depicted in the diagrams in Figure 33 (eastbound) and Figure 34 (westbound).

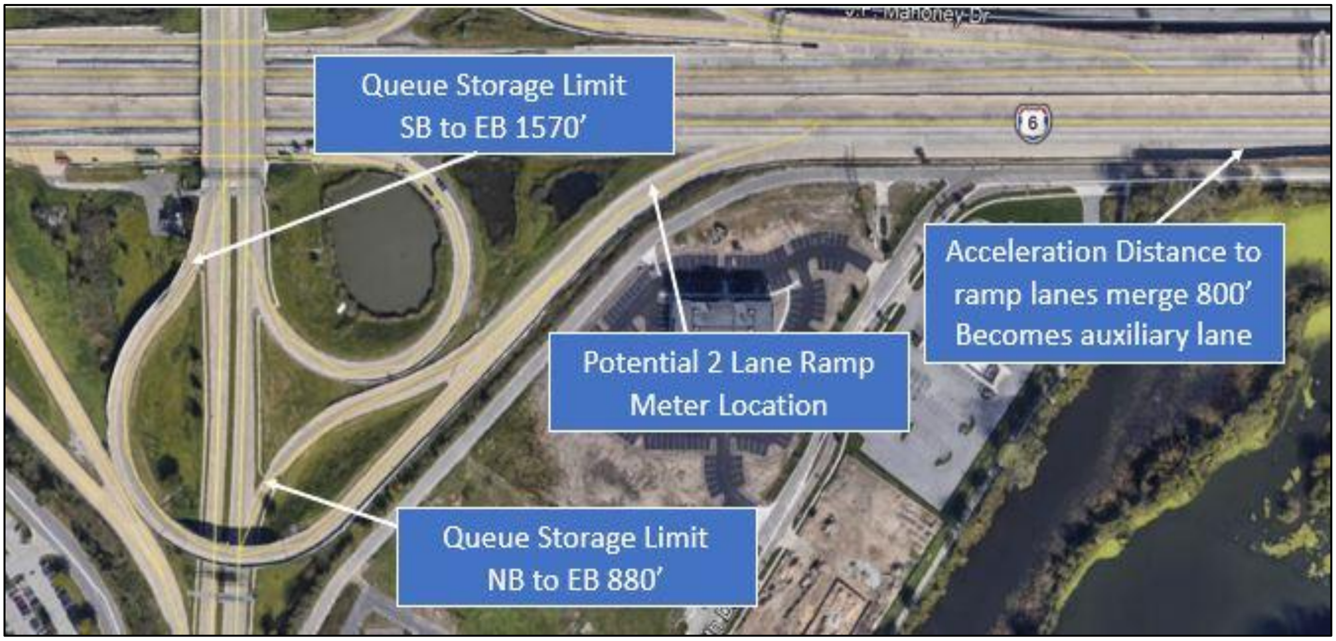


Figure 33: EB Kennedy Avenue at I-80/94

Figure 34: WB Kennedy Avenue at I-80/94

At this interchange, the eastbound on-ramps merge together from the north and south directions of Kennedy Avenue. There is reasonable storage of approximately 1570 feet available along the southbound on-ramp and also reasonable storage of approximately 880 feet available along the northbound on-ramp. The two on-ramps merge and can be metered together in staggered (alternating) two-lane metering. There is adequate merging distance of approximately 800 feet before the on-ramp lane becomes an auxiliary lane along the I-80/94 mainline.

The two westbound on-ramps are separate ramps that merge together after the southbound on-ramp gore point. After the two on-ramps merge, they form an auxiliary lane along the I-80/94 mainline. In the existing configuration, the two on-ramps would likely be metered separately with single-lane ramp meters. Both on-ramps have moderate storage distances of approximately 850 feet and approximately 700 feet for the southbound and northbound on-ramps respectively.

I-80/94 at Cline Avenue

The Cline Avenue interchange is a partial cloverleaf interchange. The ramp metering was evaluated based on the information depicted in the diagrams in Figure 35 (eastbound) and Figure 36 (westbound).

Figure 35: EB Cline Avenue at I-80/94

Figure 36: WB Cline Avenue at I-80/94

In this interchange, the eastbound on-ramps merge together from the north and south directions of Cline Avenue. There is excellent storage of approximately 2600 feet available along the southbound on-ramp and also excellent storage of approximately 2100 feet available along the northbound on-ramp. The two on-ramps merge and can be metered together in staggered (alternating) two-lane metering. There is adequate merging distance of approximately 2900 feet before the on-ramp lane becomes an auxiliary lane along the I-80/94 mainline.

The westbound on-ramps merge together from the north and south directions of Cline Avenue. There is reasonable storage of approximately 1600 feet available along the southbound on-ramp and excellent storage of approximately 2800 feet available along the northbound on-ramp. The two on-ramps merge and can be metered together in staggered (alternating) two-lane metering. There is adequate merging distance of approximately 835 feet before the on-ramp lane becomes an auxiliary lane along the I-80/94 mainline.

I-80/94 at Burr Street

The Burr Street interchange is a modified diamond interchange with single on-ramps for both the eastbound and westbound directions. The ramp metering was evaluated based on the information depicted in the diagram in Figure 37.

In this interchange, the eastbound on-ramp serves both the northbound and southbound traffic from Burr Street. For this configuration, a single lane ramp meter is assumed. There is reasonable storage of approximately 1300 feet available along the northbound on-ramp and also reasonable storage of approximately 900 feet available along the southbound on-ramp. The single lane on=ramp becomes an auxiliary lane along the I-80/94 mainline.

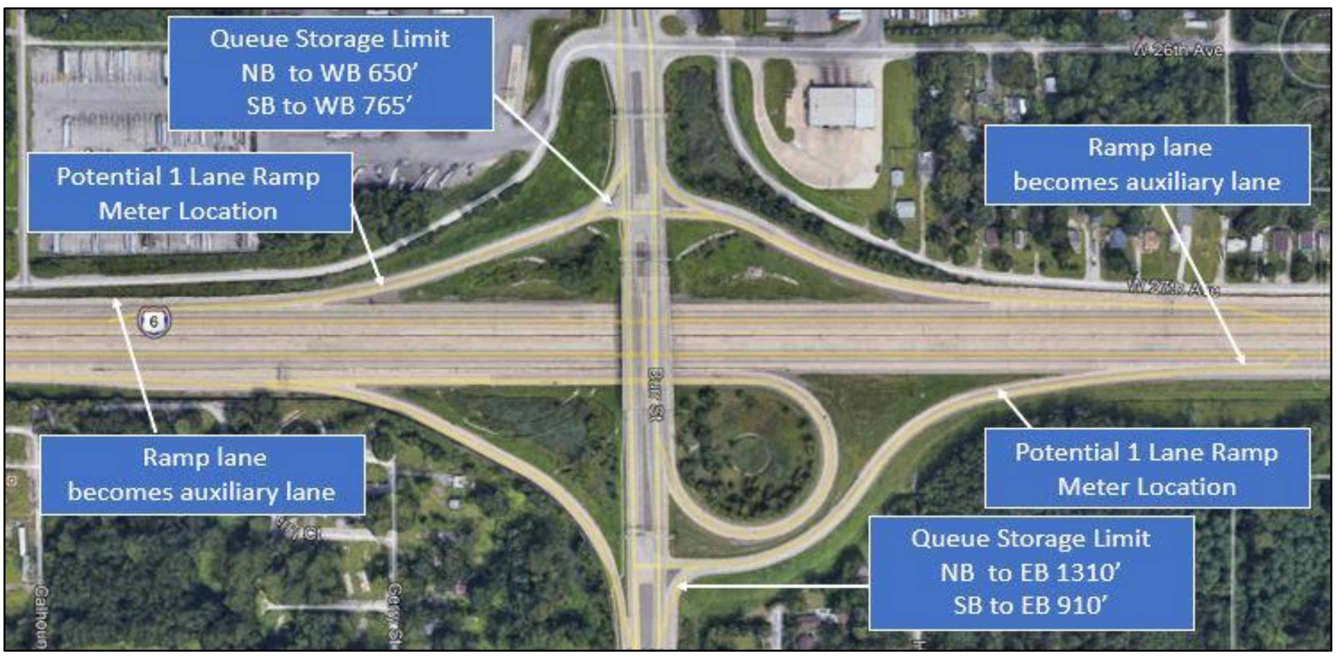


Figure 37: Burr Street EB and WB at I-80/94

The westbound on-ramp serves both the northbound and southbound traffic from Burr Street. For this configuration, a single lane ramp meter is assumed. There is moderate storage of approximately 650 feet available along the northbound on-ramp and also moderate storage of approximately 750 feet available along the southbound on-ramp. The single lane on-ramp becomes an auxiliary lane along the I-80/94 mainline.

I-80/94 at Grant Street

The Grant Street interchange is a partial cloverleaf interchange. The ramp metering was evaluated based on the information depicted in the diagrams in Figure 38 (eastbound) and Figure 39 (westbound).

Figure 38: EB Grant Street at I-80/94

Figure 39: WB Grant Street to I-80/94

In this interchange, the eastbound on-ramps are separate ramps that merge together after the northbound on-ramp gore point. After the two on-ramps merge together, they form an auxiliary lane along the I-80/94 mainline. In the existing configuration, the two on-ramps would likely be metered separately with single-lane ramp meters. Both on-ramps have reasonable storage distances of approximately 1325 feet and 750 feet available along the southbound and northbound on-ramps respectively.

The westbound on-ramps are separate ramps that merge together after the southbound on-ramp gore point. After the two on-ramps merge, they form an auxiliary lane along the I-80/94 mainline. In the existing configuration, the two on-ramps would likely be metered separately with single-lane ramp meters. Both ramps have moderate storage distances of approximately 925 feet and 1300 feet available along the southbound and northbound on-ramps respectively.

I-80/94 at Broadway

The Broadway interchange is a partial cloverleaf interchange. The ramp metering was evaluated based on the information depicted in the diagrams in Figure 40 (eastbound) and Figure 41 (westbound).

Figure 40: EB Broadway to I-80/94

Figure 41: WB Broadway to I-89/94

In this interchange, the eastbound on-ramps are separate ramps that merge together after the northbound on-ramp gore point. After the two on-ramps merge, they form an auxiliary lane along the I-80/94 mainline. In the existing configuration, the two on-ramps would likely be metered separately with single-lane ramp meters. Both on-ramps have reasonable storage distances of approximately 1300 feet and 850 feet available along the southbound and northbound on-ramps respectively.

The westbound on-ramps are separate ramps that merge together after the southbound on-ramp gore point. After they merge, the two on-ramps form an auxiliary lane along the I-80/94 mainline. In the existing configuration, the two on-ramps would likely be metered separately with single-lane ramp meters. Both on-ramps have moderate storage distances of approximately 950 feet and 1315 feet available along the southbound and northbound on-ramps respectively.

PRELIMINARY RECOMMENDATION

Description

In general, the interchanges along the I-80/94 corridor show a moderate to reasonable feasibility for ramp metering. Since almost all merging ramp lanes become an auxiliary lane to the next interchange, acceleration distances are not an issue or consideration. Storage distances and ramp traffic demands will become the determining factor in the application of ramp metering. The above review illustrates the most on-ramps have either a moderate storage length of less than 1000 feet and some a reasonable storage length of over 1000 feet. A couple of on-ramps have excellent storage lengths of approximately 2000 feet. No on-ramps have less than 500 feet of storage or a poor rating.

Based on the above results, it is recommended to proceed with ramp metering as a possible strategy in the traffic operations (micro-simulation) analysis. This testing will demonstrate if the on-ramp traffic demands are too high for the available storage to prevent excessive queuing or congestion along the on-ramps or adjacent arterials. If this is shown to be an issue, additional testing can be conducted to possibly explore improving the ramps (widen for additional metered lanes or move the previous ramp meter placement) to mitigate these conditions.

Planning or high level cost estimates have been prepared for the ramp metering system and these are summarized below in Table 7.

Table 7: High Level Costs – Ramp Metering

DESCRIPTION	UNIT COST	Quantity	Subtotal
RAMP METERING EQUIPMENT, POWER, AND COMMUNICATIONS	$243,663	7	$1,705,646
INTEGRATION AND TESTING	$22,000	7	$154,000
RAMP METERING CONTROL SOFTWARE.	$150,000	1	$150,000
	TOTAL:		$2,009,646

Key assumptions related to the high level cost estimates include:

- The approximate costs for the field elements required for ramp metering is approximately $266,000 per interchange. This cost includes cabinets, signals, cabling, integration, testing, and connections to power and communications. This cost does not include mobilization/demobilization and maintenance and protection of traffic. These related costs are included in the consolidated cost estimate in Appendix B.
- A centralized ramp metering control system that supports a corridor wide optimization algorithm is estimated to cost approximately $150,000. However, this deployment cost could increase with full integration into the rest of the INDOT systems. It is anticipated that the proposed ramp metering system described for the study corridor would utilize the same mainline detection as the rest of the ATMS and ATM features. Consideration will need to be given for the real time integration of the data and systems.

ITEMS THAT NEED FURTHER INVESTIGATION AND OR RESOLUTION

- Ramp metering will need to be analyzed using the traffic operations model and the output used to determine if there are potential queuing or operational issues that need to be address.
- A corridor wide ramp metering algorithm needs to be selected.
- Exact locations of the ramp meters will be identified after the metering is added to the traffic operations model.
- The metering strategy, while the outside shoulder is open, still needs to be fully reviewed and fine-tuned.

Managed/Special Purpose Lanes

The Managed Lane/Special Purpose Lanes concept may vary in specific definition from one agency to the next, but all the definitions have common elements:[v]

- The managed lane concept is typically a "freeway-within-a-freeway" where a set of lanes within the freeway cross section are separated from the general-purpose lanes.
- The facility incorporates a high degree of operational flexibility so that over time, operations can be actively managed to respond to growth and changing needs.
- The operation of and traffic demand on the facility is managed using a combination of tools and techniques in order to continuously achieve an optimal condition, such as free-flow speeds.
- The principal management strategies can be categorized into three groups: pricing, vehicle eligibility, and access control.

Examples of operating managed lane projects include high-occupancy vehicle (HOV) lanes, value priced lanes, high-occupancy toll (HOT) lanes, or exclusive or special use lanes. Each of these concepts offers unique benefits; therefore, careful consideration is given to study goals and objectives in choosing an appropriate lane management strategy or combination of strategies. Study goals may include increasing transit use, providing choices to the traveler, or generating revenue.

A diagram is shown in Figure 42 that captures the potential lane management applications that fall into this broad definition of "managed lanes." On the left side of the diagram are the applications of a single operational strategy—pricing, vehicle eligibility, or access control:

- *Pricing* — Includes both traditional toll lanes and toll lanes that use congestion pricing, where price is varied during certain time periods in order to manage traffic demand (e.g., peak-period surcharge or off-peak discount).
- *Vehicle eligibility* — The lanes are managed by allowing certain vehicles or restricting others; minimum vehicle occupancy is an example of an eligibility restriction.
- *Access control* — An example would be express lanes where all vehicles are allowed but access is limited during long stretches of the facility, minimizing turbulence in the flow of traffic.

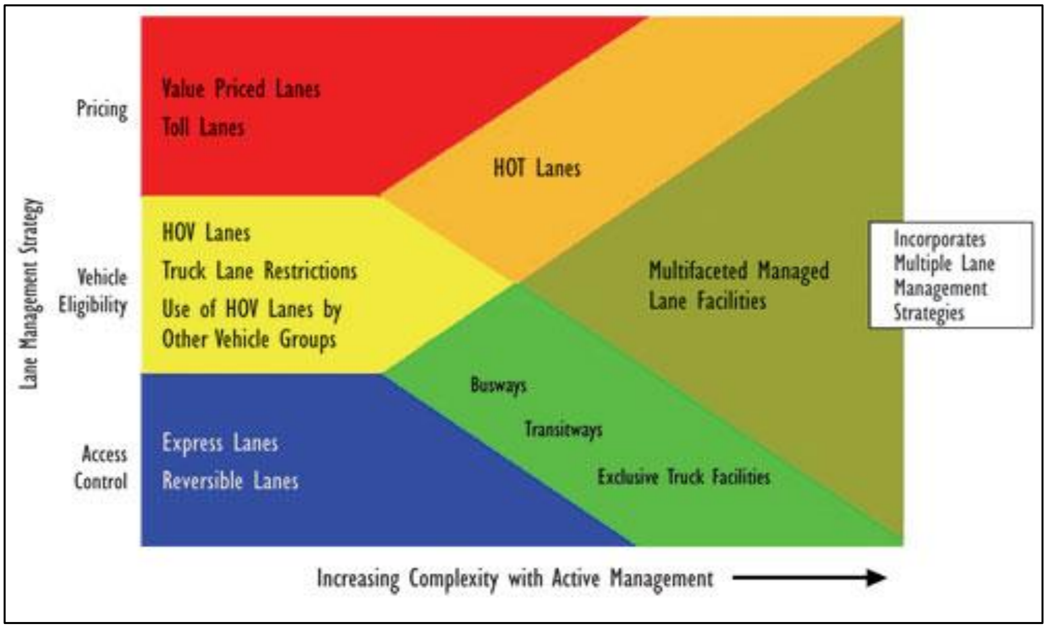


Figure 42: Managed Lanes Complexity Diagram

CORRIDOR SPECIFIC DETAILS

Operational considerations

INDOT recently reviewed the potential for more toll solutions in the state. Based on that review, INDOT determined that no new tolls will be implemented – at least for a while. With this background information, any Managed Lane strategy that involves tolling in any form, will be removed from consideration.

The implementation of any form of managed lanes will require appropriate messaging and some level of enforcement. With five lanes and the potential for dynamic shoulder lanes on the inside and outside lanes, there will be almost no areas for enforcement within the study corridor. However, the outside shoulder will likely only be used in extreme circumstances, thereby providing some opportunities for enforcement.

While there are significant truck volumes in the study corridor, and considering that there is up to five lanes of traffic and several truck origin and destination locations adjacent to the corridor, the use of the left shoulder for Truck Only traffic is likely to result in significant weaving issues for trucks to move from the right lanes all the way to the left lanes.

The corridor has high truck usage throughout the day, however transit and intercity bus volumes are not significant.

With respect to potential reversible lane options, initial reviews of the traffic volumes during the weekday peak periods indicate that although there are higher traffic volumes in the peak direction of flow (i.e., peak direction is eastbound in the morning peak period), the traffic volumes in the non-peak direction are still significant enough that a lane could not be removed for use in the peak direction without creating congestion in the non-peak direction. For other days experiencing significant traffic flow beyond the typical weekday, traffic volumes on Sunday evenings and Friday evenings (primarily during the summer season) do standout as noted earlier (Figure 13 and Figure 14) and suggest that a reversible lane operation may not be appropriate during these high traffic flow days as well.

A review of the origin destination patterns along the corridor suggests that there is a significant amount of through traffic that is traveling a significant portion of the study corridor, especially in the westbound direction. As shown in Table 8 below, approximately 33% of the traffic from the eastern extents of the study area travel the entire distance of the corridor during the AM peak period and approximately 41% during the PM peak period. In the eastbound direction, approximately 22% of the traffic from the western extents of the study area travel the entire distance of the corridor during the AM peak period and approximately 20% during the PM peak period. The travel patterns represented by these figures indicate that a high percentage of the traffic could remain in the left lanes of the corridor, and specifically between the key interchanges at I-94 and I-65. These traffic patterns therefore suggest that express lanes or inside should lane operations could be well used.

Table 8: Key Origin Destination Patterns

	Origin: I-94 EAST	
	6-9 AM	3-6 PM
Destination	**Percentage**	**Percentage**
IL-394 / I-94	10%	9%
IL-65	17%	20%
I-80 (West)	33%	41%
Other	40%	30%

	Origin: I-94 WEST	
	6-9 AM	3-6 PM
Destination	**Percentage**	**Percentage**
IL-394 / I-94	28%	27%
IL-65	13%	13%
I-94 (East)	22%	20%
Other	38%	40%

Physical Infrastructure Considerations

Recognizing that widening of the roadway as part of any strategy is not expected, there will be no space for any kind of buffer between the dynamic shoulder lanes and the mainline lanes. In addition, the shoulder widths are limited in areas, so maximum speeds are proposed to be reduced for the shoulder lanes.

The existing pavement in the shoulders is generally 15" of PCCP on 9" of compacted aggregate subbase on subgrade treatment. There are no load transfer tie bars between the shoulder and mainline lanes.

PRELIMINARY RECOMMENDATION

Description

Given the operational and physical restrictions in the study corridor, most managed lane strategies are not applicable. Furthermore, noting that trucks are already restricted to only use the right two lanes, the shoulder widths are constrained, and there are no load transfer bars, it seems that trucks should be restricted from using the inside shoulder.

On the other hand and noting the existing traffic patterns, there is the potential to treat the inside shoulder as a limited access express lane. This potential strategy will be explored through further traffic analysis using the traffic operations model (micro-simulation) to see if this strategy shows an improvement in overall operations.

HIGH LEVEL COSTS

There are very limited costs to restrict trucks from traveling in the inside shoulder. There is existing signing located in the corridor, but given the importance of restricting trucks from using the inside shoulders in order to extend the shoulder structural section life, additional signing is recommended to emphasize the restriction. Added costs for the additional signing could be between $80,000 and $100,000.

ITEMS THAT NEED FURTHER INVESTIGATION AND OR RESOLUTION

- Results of the traffic analysis will help determine if an Express Lane concept makes sense.
- If an Express Lane is desired, striping and signing for the lane within a very limited cross section width will need to be explored.

Work Zone Management

Work zones play a key role in maintaining and upgrading the nation's roadways. Unfortunately, daily changes in traffic patterns, narrowed rights-of-way, and other construction activities often create a combination of factors resulting in vehicle crashes. These crashes, while resulting in injuries and fatalities, also cause excessive delays, especially given the constrained driving environment. Based on past research, work zones account for an estimated 10 percent of overall congestion and 24 percent of unexpected freeway delays.

CORRIDOR SPECIFIC DETAILS

Operational Considerations

The ability to continue to provide safe and efficient roadway maintenance was a key issue that was brought up by many of the stakeholders that were interviewed. The cleaning of drainage inlets as well as snow and debris removal were identified as key considerations.

There is also expected roadwork in the study corridor, including a planned major structural section rehabilitation in 2035 to 2040.

Significant traffic throughout the day and heavy truck traffic add to the importance of maintaining safe and efficient work zones in the corridor.

Physical Infrastructure Considerations

The current study corridor includes four to five lanes of traffic in each direction. With the deployment of dynamic shoulder lanes and the lane control signs, gantries will extend across the entire roadway. DMS will be placed above all lanes and hard shoulders. Queue warning and VSL functionality will warn motorists of upcoming congestion and help slow speeds in a stepped down fashion. Together, the field equipment and systems associated with these strategies will enable effective and safe work zone management.

PRELIMINARY RECOMMENDATION

Description

As indicted above, other aspects of the solution will provide infrastructure that help to support work zone management. Based on past experience and input from key stakeholders, it is recommended that the system provides the following Work Zone specific functionality:

- The VSL modules should allow operators to set maximum speeds throughout a work zone and use the same step-down logic as used for VSL to slow traffic prior to the work zone.
- Lane control signing should provide the ability to close and open any lane or shoulder. The system should provide for appropriate advanced signing to move traffic one lane at a time to avoid closed lanes.
- The system should provide the ability to put planned events into the system prior to the time of the closure and provide for advanced messaging to warn motorists of the upcoming work and lane closure.
- The system should allow for automated advanced DMS messaging that provides motorist the information needed to consider alternate routes in advance of approaching decision points.
- The system should provide adequate CCTV coverage to monitor the entire work zone and all associated DMS signing and lane control.
- The solution should provide the ability to manage and store work zone and maintenance contacts for easy access by the operators.
- The solution should provide adequate detection to monitor work zone speeds and approximate end of queues within the corridor.
- The solution should provide an interface to adjacent ATMS to pass work zone details and allow for advanced signing through the other ATMS.

HIGH LEVEL COSTS

The current INDOT systems do support Work Zone management and incident management. However, with dynamic shoulder lanes, lane control, variable speed limits, queue warning, and ramp metering, there is an opportunity to provide a more advanced solution as described above. Work Zone management features should include any ATM software used to manage the strategies identified above. If INDOT develops their own ATM system, adding the appropriate work zone management support to the system should cost between $50,000 and $100,000 above the basic ATM functionality

ITEMS THAT NEED FURTHER INVESTIGATION AND OR RESOLUTION

- As indicated above, several aspects of the work zone management are dependent on other system components including variable speed limits, queue warning, and lane control. Full system functionality requirements will need to be defined with all components addressed.

Other Enhanced ITS Strategies

In addition to the TSMO strategies listed above, there are several strategies that are common to most ATMS deployments. While these strategies, listed below, do not individually represent key aspects of an overall solution, they each can play a role in improving the operation and efficiency of the corridor. INDOT already implements most of these strategies throughout the state.

- Event Management
    - Traffic Incident Management
    - Special Event Management
    - Emergency management
    - Maintenance and construction activity coordination
- Road Weather Management Road weather information systems enhancements
- Active demand management
- Traffic surveillance
- Travel time-based decision support
- Computer-aided dispatch integration
- Advanced transit operations management or integration
- Smart Lighting and LED replacements

In this section, a description of each strategy is provided along with a discussion on how they are expected to fit within the corridor, as well as how they may be expanded to support the corridor needs.

CORRIDOR SPECIFIC DETAILS

INDOT currently operates three Traffic Management Centers (TMC), including one in Indianapolis and Gary.

The Indianapolis TMC is the only center that operates 24/7/365. The center has five operators during the AM and PM peak periods and one operator overnight unless snow operations are in effect. At all other times, the center has four operators available. The center has six workstations available and can expand to accommodate eight workstations during emergencies. There is also the ability to add staff in remote offices to support the operations center.

The Gary TMC is currently open from 6:00 AM to 10:00 PM. This center is typically staffed with two operators. The operations staff are contracted employees, through an operations support contract. The staff manage and operate the regions ITS devices, dispatch Hoosier Helpers, and coordinate between emergency response (law enforcement and Fire department) and the State's maintenance staff that support the clearance of the roadway. The Gary TMC and Indianapolis TMC staff share the same systems.

INDOT currently uses an Iron Mountain system and IRIS (Intelligent Roadway Information System). Iron Mountain is INDOT's legacy ATMS and is used to enter event details through the Global Event Manager (GEM). All activity and events are logged and tracked in the GEM. Based on the event details, the Iron Mountain system recommends messages to be displayed on the DMS.

IRIS is an open-source Advanced Traffic Management System (ATMS) software developed by the Minnesota Department of Transportation. This system is used by transportation agencies to monitor and manage interstate and highway traffic. The system is an integrated platform for transportation agencies to manage traffic monitoring and control devices. The IRIS software presents a map-based interface to system operators and the system is currently used to view and control the region's CCTV.

The IRIS base software is written in Java and licensed for anyone to use under the GPL. In addition, all dependencies required to install and operate an IRIS system are available as free software. The software has a client/server architecture. System configuration data is stored in a PostgreSQL database and managed by the IRIS server. The server also handles communication with all traffic control and data collection devices. The client software is distributed by an Apache web server, using Java Web Start. All communication between the server and clients is encrypted using transport layer security (TLS). The server may be configured to pass authentication requests off to an external LDAP server, allowing IRIS to integrate into an existing authentication system. INDOT is modifying the IRIS core software to be web based.

Information is passed to the public through the CARS 511 system. There is currently limited integration between the systems and some duplicate entry is required by the operators to manage events and fully utilize the ITS infrastructure.

There is currently some coordination between the Gary TMC and other agencies through the Great Lakes Regional Transportation Operations Coalition (GLRTOC). The GLRTOC includes transportation agencies responsible for operations on major transportation routes stretching from Minneapolis, Minnesota to Toronto, Ontario (Canada). The GLRTOC was formed in May 2010 with a core mission to collaborate on improving cross-regional transportation operations in support of regional economic competitiveness and improved quality of life. The major GLRTOC goals include incident management, improved freight operations, work zone coordination, and regional coordinated traveler information. The GLRTOC three strategic focus areas include freight operations, reliability and mobility strategies, and traffic incident management/emergency transportation operations.

The systems used in Indiana do not currently have support for the ATM functions recommended for this project. Support for dynamic shoulder lanes, lane control, variable speed limits, queue warning, and ramp metering will need to be added.

PRELIMINARY RECOMMENDATION

Description

Provide Optimal ITS Device Deployment. While installing the lane control gantries, ITS equipment and communications required to support the ATM strategies described above should also be coordinated for efficiently implementation. This installation creates an opportunity to ensure that the State has optimal ITS devices, systems, and inter-agency connections to provide the best possible event management, Road Weather Management, Active demand management and traffic surveillance. For the most part, the equipment required for the ATM will provide very good coverage for vehicle detection, CCTV and DMS.

The State may also want to consider a few additional RWIS stations in the corridor. RWIS stations would allow for accurate automated weather responses to improve safety and minimize delays resulting from weather related crashes.

Leverage VSL and Queue Warning Equipment. Variable Speed Limit and Queue Warning strategy needs will require more vehicle detection stations throughout the corridor. This added detection can also be used to provide very timely and more accurate travel times through the corridor. These travel times should be used to drive DMS travel time messages and ATIS feeds as well as to share with adjacent agencies to support Active Demand Management strategies and encourage broader alternative routes or modes during times of significant congestion.

Optimize Data and Image Sharing. Dynamic Shoulder Lane functionality will require that the ITS design provides sufficient additional cameras to allow for rapid confirmation of shoulder conditions throughout the corridor which in turn will permit the safe opening of the shoulder lanes. The use of these cameras should be leveraged to help optimize all event responses. Camera images should be made available to the TMC, INDOT maintenance and Indiana State Police Dispatch to support quick and accurate responses. In addition, the State should consider image sharing with IDOT, Illinois Tollway, and the Indiana Toll Authority.

Center to Center Interfaces. The full ATMS solution should include full comprehensive near real time sharing of traffic and event data, as well as roadway images between INDOT, IDOT, Illinois Tollway and the Indiana Toll Authority. The study corridor (I-80/94) is a major connector between these regions and significant issues in the study corridor can have a large impact on traffic throughout the region. Rapid and accurate coordination between the agencies can significantly reduce impacts and help motorists make good decisions relating to their travel.

As discussed in other sections of this report, there are very limited alternate routes within the project limits that could readily be used for ICM strategies without a very significant investment. However, there are alternate routes outside the project limits that may be appropriate alternatives for some motorists when there are significant events on the study corridor – see Figure 43. Providing near real time interfaces with adjacent systems will allow these systems to promote the use of these alternatives when there is significant congestion within the study corridor: For example:

- For motorists traveling to or from Downtown Chicago and the Indiana Toll Road – I- 90 is a good alternative.
- For motorists traveling to or from I-65 - Route 30 is a viable option.
- Route 20 is a reasonable option for motorists traveling to or from I- 90 and I-94 in Indiana and to or from I-80 in Illinois.

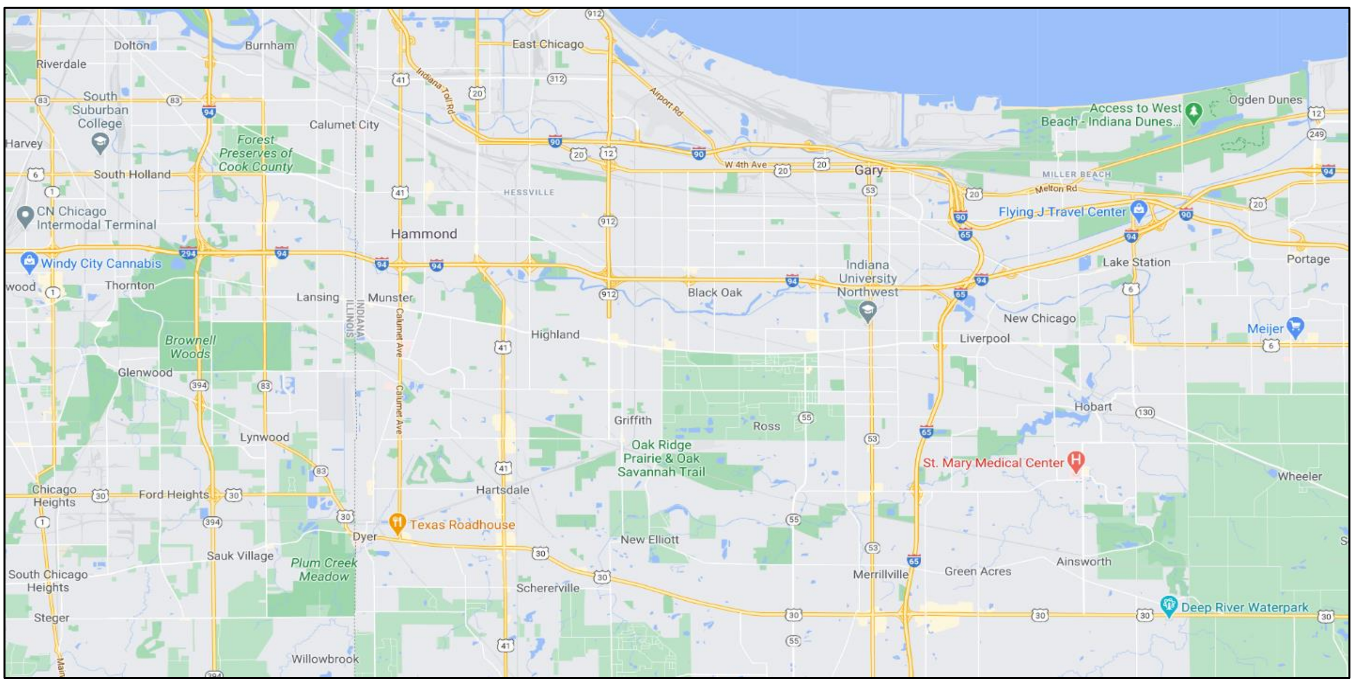


Figure 43: Wide Area Alternate Routes - I-90, US 20, US 30

Computer Aided Dispatch (CAD) Integration. Given the heavy traffic and now the potential use of the shoulders to improve throughput, rapid identification and response to roadway incidents is even more important. ATMS system integration with the Indiana State Police dispatch will shorten detection times and support a coordinated response. ATMS CAD integration is becoming more and more popular and has proven to be an effective measure in minimizing response and clearance times.

Advanced Transit Operations Integration. The overall solution should provide integration with and promote the use of transit options when there are major delays in the corridor. While transit is not a major contributor to people movement alternatives in the study corridor, there are rail options available. Coordination with and promotion of these other mode options does not add any significant costs to the overall solution.

Smart Lighting and LED Replacements. This strategy is presented as an option to consider in conjunction with the potential implementation of other strategies. It is understood that INDOT has a planned project to replace the lighting along the study corridor with LED lights in about a year. If this planned project is delayed or canceled, there is an opportunity to seek efficiencies by adding this work to the overall TSMO solution being contemplated for the study corridor. Specifically, there could be cost savings related to LED and smart lighting installation as part of the installation of the lane control gantries, ITS equipment, and enhanced communications throughout the study corridor. In the long term, LED lights will save a significant amount in electricity costs and smart lighting can also provide for enhanced lighting during times of incidents and maintenance while improving safety and comfort for the motorists and the workers. Currently INDOT has not considered the use of any smart lighting options.

HIGH LEVEL COSTS

Provide Optimal ITS Device Deployment. The ATM strategies will provide a significant amount of additional equipment to the corridor. The costs to integrate the new equipment into the full ATMS responses is discussed in the subsequent subsections below. The costs to add two fully equipped RWIS stations, one near each end of the corridor, are estimated to be approximately $250,000.

Leverage VSL and Queue Warning Equipment. If an "off-the-self" ATM central software is selected, the State should include an interface to the existing ATMS platform to allow for the sharing of data from the new ATM field equipment deployed in the study corridor. Typically, an ATM platform would support a standards-based interface, but some costs should be expected (on both sides) to work through integration details and to undertake integration testing. Costs to support the interface activities are estimated to be in the range of $50,000 to $100,000 for both sides.

Optimize Data and Image Sharing. Leveraging the added camera images to make them available to the TMC, INDOT maintenance and Indiana State Police Dispatch, and other agencies (e.g., IDOT, Illinois Tollway and the Indiana Toll Authority) will require communications connections between the various systems and a means to share video in a controlled fashion. The existing ATMS or selected ATM platform should allow for video sharing between agencies with appropriate controllable rights. An allowance of approximately $50,000 has been assumed to configure the system as well as to develop and provide basic training for the agencies. Other applicable costs to connect the various agency systems is discussed below.

Center to Center Interfaces. There are two primary costs associated with providing interfaces between the various agency ATMS - physical connection costs and system interface development and integration costs. Fortunately, all of the key agencies have fiber networks that are either adjacent or very closely located to the study corridor. Based on the limited connections distances, costs for the physical connection of the networks are estimated to be approximately $25,000 for ISTHA, $50,000 for the Indiana Toll Authority, and $100,000 for IDOT.

Conversely costs for system interfaces can vary greatly, therefore an allowance of approximately $50,000 per side per interface has been assumed at this time. Ideally INDOT would have one interface that can support IDOT, ITA and ISTHA, however a single interface is not always possible. Based on the above high level cost estimate assumptions, a total cost estimate between $150,000 and $250,000 has been identified for the system interfaces including development, system integration testing, and documentation.

Computer Aided Dispatch (CAD) Integration. The study team has built many interfaces between ATMS and 911 CAD systems. However, the costs can vary greatly and depend on the CAD system and the nature of the interface (one-way or two-way). The costs also depend on the actual ATM and whether the ATM is already designed to accept events from external systems. The CAD -ATM(S) integration cost is estimated to be in a range between $20,000 and $150,000.

Advanced Transit Operations Integration. Once a standards-based C2C interface is available within the ATM(S), this interface could also be made available to transit agencies to provide event and traffic delay information. For the purposes of developing system interface cost estimates, it is assumed that any costs associated with the transit agency system side would be the responsibility of the transit agency.

The actual responses that promote transit alternatives could be built into the ATM or ATMS responses without incurring any significant additional costs. More complicated coordinated responses could be considered, however, given the limited transit alternatives in and adjacent to the study corridor, this additional effort and associated costs may not be justified.

ITEMS THAT NEED FURTHER INVESTIGATION AND OR RESOLUTION

- All of the cost estimates included in this section are preliminary and are provided as order of magnitude costs only, recognizing that these costs can vary greatly depending on the details. These details will be investigated further as part of the detailed design for the selected items.
- Developing the appropriate center to center integration between INDOT, IDOT, Illinois Tollway and the Indiana Toll Authority will require a series of meetings to discuss details and develop agreements.

Maintenance and Operational Enhancements

A common theme through most of the stakeholder interviews was the importance of, and difficulties related to, roadway operations and maintenance along the study corridor. With substantial overall traffic volumes as well as significant truck volumes, even minor issues along the freeway can quickly lead to major congestion. In addition to the system related strategies discussed above, it is important and cost effective, to investigate opportunities to improve, upgrade, and refine operational and maintenance practices. Based on the interviews, field reviews and research on existing practices, the following potential operational upgrades and refinements have been identified:

Towing and Recovery Incentive Program (TRIP): TRIP was first introduced in Florida over 10 years ago and has since been expanded to other jurisdictions in the US. The program standardizes the towing operator's response to incidents involving heavy commercial motor vehicles and provides a monetary incentive to the towing operator to arrive on-scene within a specified period of time (30-45 minutes depending upon location); clear the incident within a specified period of time (typically 90 minutes); and do so in a safe, responsible manner (e.g., proper PPE for all towing company responders). Incidents that require a TRIP activation involve heavy commercial vehicles (or other large vehicles that are blocking lanes or involve a recovery that will require one or more lanes to be blocked. Within the existing programs, the TRIP towing companies must deploy a minimum of a 50-ton wrecker, a 35-ton wrecker and a support vehicle that carries a pre-defined complement of tools and equipment to each TRIP event. Towing operators who fail to achieve the established performance goals may be subject to a disincentive provision. The above are all goals that align with those of INDOT as they relate to safety and implementing innovative strategies that save lives.

The TRIP program has generated a positive benefit/cost ratio in each jurisdiction in which it has been implemented. For example, the Georgia DOT commissioned an independent study by a leading consulting firm which determined a benefit/cost ratio of 11:1 for the Atlanta area TRIP program, with savings generated by reductions in vehicle hours of delay, secondary crashes, vehicle emissions, and fuel consumption. In Virginia, the Virginia Transportation Research Commission studied the Richmond area Virginia DOT TRIP program and found similar benefits were realized over the first 18 months of operation.

The setup and operation of a new TRIP along I-80/94 study corridor would involve several steps, including:

- Outreach/Education to Key Stakeholders
- Specific TRIP activation training for Key Stakeholders
- Outreach to Secondary Stakeholders
- Program Application Process for interested Towing Companies
- Site and Equipment Inspections
- Recovery Zone Development
- Program Management (documentation, record keeping, oversight/review, monthly reviews meetings, performance measures, towing company incentive payments, etc.)

Winter Roadway Operations Changes: Typically snow removal along the study corridor is performed with a group of plows staggered such that the snow is pushed from the left lane to the right shoulder in a single pass. If the inside shoulder is to be used as a travel lane during the winter months, an additional plow would be needed to clear the inside shoulder along with the rest of the traveled lanes. With the need to clear the inside shoulder along with the mainline lanes simultaneously, one additional plow and two additional drivers to cover operational needs. INDOT recently implemented a Smart Plowing solution that will also add to the efficient snow removal operation. The Smart Plow solution incorporates real time weather information to optimize salt distribution, plow times, and overall plowing operations.

Augmented Road Raking and Sweeping for Debris: Currently debris is removed from the shoulders a few times a week, or from the traveled lanes as needed. The shoulder is raked for larger debris and then swept. Given the large amount of debris that collects along the study corridor, the inside shoulder may need to be raked and swept prior to each opening. Furthermore, with the intent to open the inside shoulder during heavy traffic periods, it is likely that the inside shoulder will need to be cleaned twice a day, Monday through Friday, and as needed on Sunday and Saturday. Current contracts for urban litter removal may also need to be enhanced to support more frequent removal of litter from the right shoulder and other off-road areas.

Maintenance and Emergency Response Agency Access to CCTV: As part of the dynamic shoulder lane deployment, sufficient CCTV are anticipated to be deployed to allow full coverage of the entire study corridor. Providing easy access of CCTV images to maintenance and emergency response staff allows these responders to review the conditions such that they can more accurately attend to an incident, instead of one person arriving on scene first and then coordinating a second response to get the appropriate crews in the field.

Enhanced Hoosier Helper Program: Currently Hoosier Helpers patrol interstates including the I-80/94 study corridor from the Illinois state line to I-90. They assist motorists and keep the highways safe by changing flat tires, fixing minor mechanical problems, removing debris from the road at the scene of an accident, providing minimal amounts of fuel, and providing emergency medical assistance. They are also trained in First Aid, CPR, Automatic External Defibrillator (AED), HAZMAT, and have completed medical helicopter training. The Hoosier Helpers are a valuable asset to numerous agencies including the Indiana State Police and local first responders in assisting with various emergencies on Indiana interstate freeways.

Under the current program the Hoosier Helper vehicles do not have the ability to tow. In an effort to minimize disabled vehicle clearance times within the study corridor, it may be prudent to add another Hoosier Helper truck in the corridor with tow capabilities. The ability to tow, would in many cases, decrease clearance times for incidents and also provide the ability for the Hoosier Helpers to help clear stalled or disabled vehicles from the inside shoulder prior to the shoulder being opened as a travel lane.

Hoosier Helpers currently operate five days a week during the peak periods, and sometimes six days during the week when needed. Consideration should be given to expanding the hours that the Hoosier Helpers are available to help in maintaining clear shoulder and travel lanes. It is noted that some of the respondents who were interviewed recommended that the Hosier Helper Program should be expanded to 24/7 on the study corridor, but others suggested that consideration be given to a separate service specific to the corridor.

Provide 90-Day Enhanced Law Enforcement at Opening: With the implementation of dynamic shoulder lanes, variable speed limits, and ramp metering, INDOT should considered enhanced enforcement to ensure that motorists follow the rules applicable to the strategies. With these types of strategies, it is common to provide enhanced enforcement in clusters, starting with the initial opening.

It is recognized that the difference in the legislation between Illinois and Indiana with regard to variable speed limits will complicate conformance and enforcement in the corridor.

Geometric Changes: Initial traffic analysis has indicated that there is an exit ramp diverging operations issue at the eastbound exit to I-65 southbound. The existing lane configuration requires that all mainline traffic must make at least one lane change to exit the freeway. Noting the high exiting volumes (>3000 vph) during the peak periods, one lane is not able to accommodate the traffic volumes exiting the eastbound mainline lanes, and thus multiple lane changes maneuvers are required. Traffic operations could be improved at this location through modification of the configuration of the exit ramp by incorporating a choice lane from the mainline shoulder lane and the ramp lane. This change in the configuration would reduce the number of required lanes changes and potentially reduce turbulence approaching the exit ramp. It is suggested that the proposed changes be first tested in the traffic operations model (micro-simulation) to ascertain the potential benefits before any further engineering work is undertaken to explore the potential costs associated with the geometric change.

In addition to this eastbound exit ramp diverging operations issue, a merging issue has been identified further east in the eastbound direction where the left lane ends and traffic is forced to merge to the right. The requirement to merge to the right does not typically meet driver expectations and is seems that there is insufficient signing to provide advance warning of the lane reduction. Reconfiguration of the eastbound lanes, east of the I-65 interchange, is one potential approach that could improve operations by maintaining lane continuity in the left most lanes. In this example, the reconfiguration of the eastbound lanes to reduce the number of lanes from four to three could be realized through the I-65 / Central Avenue Interchange with modifications to the collector / distributor lanes and the concrete barrier placement. It is suggested that the proposed changes be first tested in the traffic operations model (micro-simulation) to ascertain the potential benefits before any further engineering work is undertaken to explore the potential costs associated with the geometric change.

Guide Signs: Guide signing throughout the corridor could be enhanced to increase positive guidance and therefore potentially affect better lane utilization across all lanes. Given the urban nature of the corridor with frequent and closely spaced interchanges, improved operations through better lane utilization could be achieved with the implementation of advance exit information such as interchange sequence signs that provide the distance to the next three interchanges. This advance information could cause some unfamiliar drivers to remain in the center lanes longer when their destination is further away rather than prematurely moving to the right lane and potentially adding to the turbulence associated with the merging and diverging traffic at the immediate interchange location.

HIGH LEVEL COSTS

Towing and Recovery Incentive Program (TRIP): Assuming a monetary incentive of $2500 per successful TRIP event ($3500 if specialized additional equipment is required) and based upon the available incident data (approximately 4800 incidents over three years; 38% involving commercial vehicles; 20% of those commercial vehicle incidents blocking lanes), approximately 8-10 TRIP events per month could be expected in this corridor that would in turn generate incentive payments of $270,000 annually. Program deployment is estimated at approximately $125,000 over a six-month schedule and program management during operation is estimated at approximately $160,000 for a 12-month term. The total cost over an 18-month project term, including incentive payments, is estimated to be approximately $555,000. Of note, several jurisdictions are successfully charging the incentive payment back to the responsible party, which if considered for this deployment along the study corridor, would reduce the program cost to $285,000 over the 18 month term. Based on the available incident data, a benefit/cost ratio similar to that experienced in Georgia and Virginia could be expected for a TRIP along the study corridor.

Winter Roadway Operations Changes: At this time, it is unclear if an additional truck would be required to address the changes in winter roadway operations, or whether just additional maintenance personnel would be required. It is understood that 72 new trucks are already on order for next year. An additional maintenance person, with a cost ranging between $40,000 and $80,000 per year, would be able to support plowing in the winter and debris removal year-round.

Augmented Road Raking and Sweeping for Debris: One additional maintenance person is suggested to support the additional plowing needs as well as to support the additional debris removal required for the dynamic shoulder lane operations.

Maintenance and Emergency Response Agency Access to CCTV: There is no significant additional cost associated with allowing maintenance and emergency response personnel access to the CCTV – as long as they are on the network.

Enhanced Hoosier Helper Program: Additional costs to INDOT will need to be investigated further.

Provide 90-Day Enhanced Law Enforcement at Opening: In the past, INDOT has supported the cost for additional law enforcement at the opening of major roadwork projects. It is anticipated that the costs for any additional enforcement upon initiating operations of the new strategies would be similarly addressed by INDOT.

Geometric Changes: Cost estimates for any proposed geometric changes will be generated once the proposed changes are first tested and confirmed in the traffic operations model (micro-simulation) and subsequent conceptual engineering is completed.

Guide Signs: Cost could vary significantly depending on the amount of changes to the existing signs as well as the inclusion of any new signs (and structures). Cost estimates will be developed once a comprehensive review is completed and a recommended design is developed.

ITEMS THAT NEED FURTHER INVESTIGATION AND OR RESOLUTION

- Confirmation of potential ongoing operational costs and how these would be covered.
- More details will need to be examined in relation to the various operational options that the State determines are potentially feasible.
- Consider cross border operational coordination for these strategies.
- The potential Geometric Changes and Guide Signs strategies need to be further developed, assessed in more detail, and discussed with INDOT.

Removed Strategies

Freeway/Arterial Integrated Corridor Management

Transportation corridors often contain underutilized capacity in the form of parallel roadways, single-occupant vehicles, and transit services that could be better leveraged to improve overall person throughput and reduce congestion. Facilities and services on a corridor are often independently operated, and efforts to date to reduce congestion have focused on the optimization of the performance of individual assets.

The vision of Integrated Corridor Management (ICM) is that transportation networks will realize significant improvements in the efficient movement of people and goods through institutional collaboration and aggressive, proactive integration of existing infrastructure along major corridors. Through an ICM approach, transportation professionals manage the corridor as a multimodal system and make operational decisions for the benefit of the corridor as a whole.

For example, Adaptive Traffic Signal Control can continuously monitor arterial traffic conditions as well as the queuing at intersections and dynamically adjust the signal timing to optimize one or more operational objectives (such as minimizing overall delays). Adaptive Traffic Signal Control approaches typically monitor traffic flows upstream of signalized locations or segments with traffic signals, anticipating traffic volumes and flow rates in advance of reaching the first signal, then continuously adjusting timing parameters (e.g., phase length, offset, cycle length) during each cycle to optimize operational objectives.

There are several factors to consider when developing ICM strategies such as alternate routing on adjacent arterials. Roadway capacity, land use, potential for upgrading or making intersection improvements, equity, and acceptance of local agencies to increased traffic are the most relevant. As required, increased signage and routing information will need to be designed and implemented as well.

The use of the parallel road network, as alternates to the I-80/94 freeway, was investigated with respect to providing extra capacity during periods of recurring and non-recurring congestion. Based on the traffic operations model limits, the following parallel roadways were reviewed as potential alternates for increasing capacity in the area through coordination with the local road network:

- Ridge Road on the south side of the freeway is a consistent parallel route throughout the study area
    - Ridge Road – Torrence Avenue in Illinois to I-65

- On the north side of the freeway, there are no continuous parallel routes and therefore four sections or parallel routes were reviewed
  - 173 Street – Hohman Avenue to Cline service road
  - W 21 Avenue / Front Street – Clark Road to Virginia Street
  - 169 Street / W 15 Street – Harrison Avenue to Michigan Street
  - 25 Avenue – New Hampshire Street to Virginia Street

The traffic operations model limits with these parallel routes identified are shown in Figure 44.

Figure 44: Model Scoping Limits

Each of these routes were reviewed with respect to the following characteristics which will affect the capacity of the roadway and the ability to be used as an alternate route for additional traffic:

- Location of cross-streets with access to I-80/94
- Location of traffic signals / signalized intersections
- Location of stop signs
- # of available through lanes
- Land use

Summary details for the parallel routes are provided below:

RIDGE ROAD FROM TORRENCE AVENUE TO I-65

- There are eight interchanges along the I-80/94 study corridor.
- 34 traffic signals / intersections are located along Ridge Road. Between Calumet Avenue and Grant Street, the traffic signals all have left turn pockets and additional turn lanes. Some sections of Ridge Road have a continuous two-way left turn lane.
- Six stop signs / stop controlled intersections are located along the route at the eastern end.
- Ridge Road is predominately configured with two through lanes in each direction between Pierce Street and Wentworth Avenue with interchanges at Calumet Avenue and Grant Street. The cross section changes to one lane in each direction on the eastern and western ends of the route.
- Land use is mostly commercial throughout the corridor.

Recommendations – Ridge Road could serve as a viable alternate route for the implementation of ICM concepts between Calumet Avenue and Grant Street. Ridge Road in this segment has a continuous four lane cross-section with turn pockets developed at the intersections, is mostly commercial in land use, and has no stop signs. The western and eastern portions of Ridge Road, however, have only one lane in each direction and/or also include stop signs. The 8-mile section of Ridge Road that could be used as an alternate route in shown in Figure 45.

Figure 45: Ridge Road Alternate Route Extents

NORTH SIDE PARALLEL ROUTE SEGMENTS

For the route segments north of the I-80/94 study corridor, the following evaluation summary is provided:

173 Street – Hohman Avenue to Cline Service Road

- There are three interchanges along I-80/94 parallel to this road segment.
- There are eight traffic signals / intersections and turn bays are developed at these locations.
- There are 10 stop signs / stop controlled intersections.
- The roadway is predominately configured with one through lane along the whole section in each direction
- The area along 173 Street is mostly residential.

Several factors listed above make the parallel route of 173 Street an undesirable candidate for an alternate route to the I-80/94 study corridor. There is only one through lane in each direction along the route and capacity is limited. There are numerous stop signs, and the area is mostly residential, which is typically an undesirable characteristic for traffic rerouting. Finally, there are only three interchange access points with I-80/94 that only extend over approximately 2.5 miles.

W 21 Avenue/Front Street – Clark Road to Central

- There are two interchanges along the I-80/94 corridor parallel to this road segment.
- There are six traffic signals / intersections with few turn lanes developed.
- There are 10 stop signs / stop controlled intersections.
- The roadway is predominately configured with one through lane along the whole section in each direction.
- The area along W 21 Avenue is mostly residential.

Several factors listed above make the parallel route of W 21 Avenue an undesirable candidate for an alternate route to the I-80/94 study corridor. There is only one through lane in each direction along the route and capacity is limited. There are numerous stop signs / stop controlled intersections and the area is mostly residential, which is typically an undesirable characteristic for traffic rerouting. Finally, there are only two interchange access points with I-80/94 that only extend over 1.0 miles. .

169 Street/W 15 Street – Harrison Avenue to Michigan Street

- There are six interchanges along I-80/94 corridor parallel to this road segment.
- There are 20 traffic signals / intersections. The traffic signals between Dewey Street and US 41 have fully developed turn lanes.
- There are 14 stop signs / stop controlled intersections.

- The roadway is mostly configured with one through lane in each direction except between Dewey Street to US 41.
- The land use along the roadway is industrial and residential on the western and eastern ends, and commercial again between Dewey Street and US 41.

There is a low to moderate potential to use the portion of 169 Street from US 41/Indianapolis to Burr Street as an alternate route to the I-80/94 corridor. The alternate route is configured with two lanes each direction with only one current stop sign at Colfax Street near Burr Street (improvements needed at this interchange). The alternate route would parallel a 4-mile section that includes three interchanges along the I-80/94 corridor. The remaining portions of 169 Street consist of only one lane in each direction with numerous stop signs / stop controlled intersections this segment undesirable for as an alternate route.

25 Avenue – New Hampshire Street to Virginia Street

- There are three interchanges along the I-80/94 corridor parallel to this segment.
- There are 12 traffic signals / intersections mostly in the section between Burr Street and Grant Street.
- There are six stop signs / stop controlled intersections mostly in the section between Grant Street and Broadway.
- The roadway is mostly configured as two through lanes in each direction with fully developed turning lanes in the section between Burr Street and Grant Street.
- The land use along this road segment is mostly commercial with residential mixed in.

There is a low to moderate potential to use the portion of 25 Avenue between Burr Street and Grant Street as an alternate route. Parallel to this alternate route segment is only a 2.5-mile section of the I-80/94 corridor where traffic can be rerouted between just two adjacent interchanges. The eastern end of this section of the alternate roadway has six stop signs / stop controlled intersections and the roadway reduces to only one lane in each direction at the Broadway interchange.

SUMMARY OF ANALYSIS FOR INTEGRATED CORRIDOR MANAGEMENT (ICM) USING ALTERNATE ROUTING

The best potential to provide alternate routing during incidents along the I-80/94 study corridor is the eight mile section of Ridge Road between Calumet Avenue and Grant Street. This is a significant stretch as the entire study corridor length from the Indiana/Illinois state line to I-65 is 12 miles. The current cross section of Ridge Road consists of two through lanes each direction with turn lanes developed at the signalized intersections for increased capacity. There are five interchanges available in this section of Ridge Road that will also traffic to move to / from I-80/94. This corridor would require additional review for potential traffic signal upgrades, roadway widening, and other infrastructure improvements to be further considered for ICM.

However, ideally, there should be consistent alternate routes available for the rerouting of traffic in both the eastbound and westbound directions. Eastbound traffic could use an alternate route on the south side of the I-80/94 corridor and westbound on the north side of the I-80/94 corridor. There is no consistent or longer segment of roadway with adequate capacity on the north side of the I-80/94 study corridor. Rerouting both eastbound and westbound freeway traffic onto Ridge Road would likely cause severe congestion and would likely not be accepted by the municipalities in the area.

Based on the above assessment, alternate traffic rerouting for Integrated Corridor Management (ICM) will not be pursued at this time.

Transit Management

This section of freeway does not directly connect full origin destination trips for many motorists. While some commuters use this section of the freeway as part of their commute, there is very few major destination points at either end of the study corridor Given the lack of strong destinations within the corridor, there are very few transit routes using the study corridor. There are also no adjacent commuter rail systems.

With very limited transit service and no adjacent commuter rail options, any Transit Management strategies would not be worth pursuing in the study corridor.

Freight Management

While there is very heavy truck traffic using the study corridor and some minor freight origins and destinations, there are no major freight facilities in the vicinity of the study corridor. As a result, implementing any freight strategies as part of an overall solution would be outside the logical scope of the study.

Tolling

In 2018, the State developed a Statewide Interstate Tolling Strategic Plan. At the conclusion of the study, it was determined that additional tolling options would not be pursued at this time. While tolling may be reviewed again as a long term strategy, tolling will not be reviewed as an option for this short-term study. This includes any HOT lanes, Congestion Pricing, Tolled Express Lanes, or any form of traditional tolling.

Connected and Automated Vehicle (CAV)

Connected and Autonomous vehicle technologies will eventually play a very significant role in the optimization of the use of roadway infrastructure. However, given the limited length, design life, budget, and diversity of traffic on the study corridor, this is not an appropriate study to be driving CAV technologies.

Transit Signal Priority

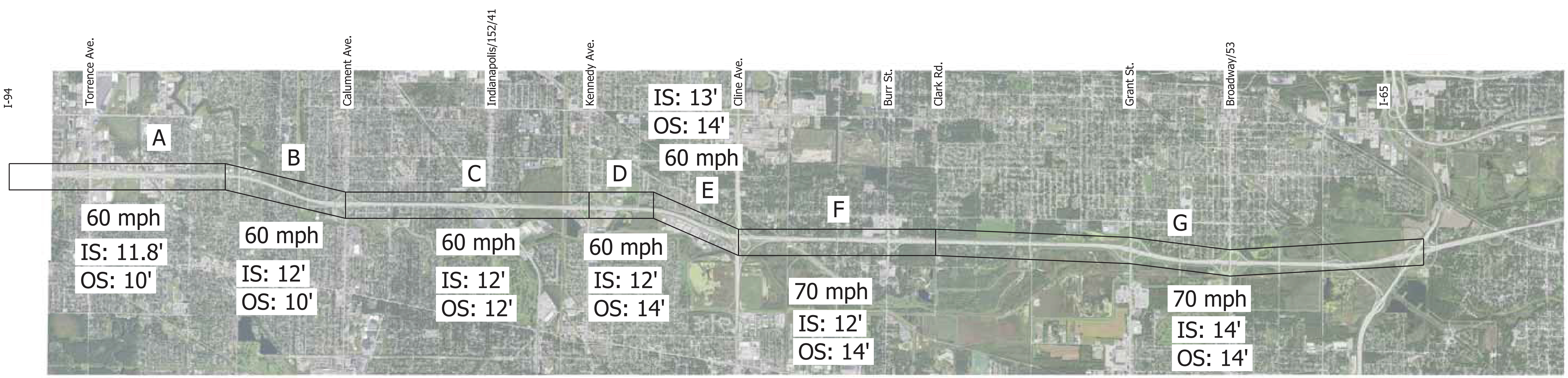
This strategy manages traffic signals by using sensors or probe vehicle technology to detect when a bus nears a traffic signal-controlled intersection, turning the traffic signals to green sooner or extending the green phase, thereby allowing the bus to pass through more quickly. In an ATDM approach, current and predicted traffic congestion, multi-agency bus schedule adherence information, and the number of passengers affected, may all be considered to determine conditionally if, where, and when transit signal priority may be applied.

Improved Bicycle and Pedestrian Crossings

Given that the focus of this study is to relieve congestion on the freeway, and no significant changes on the arterials are anticipated, improved bicycle and pedestrian crossing strategies do not apply to this study.

Appendix A: Potential Typical Sections

See the following pages



Shoulder Widths derived from existing plans and measurements from aerials. Exact widths will need to be confirmed with survey
"IS": Inside Shoulder
"OS": Outside Shoulder
Segments D, F & G: "OS" is 14' paved with barrier, 12' paved+2'usable without barrier

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DESIGNED: ______ DRAWN: ______

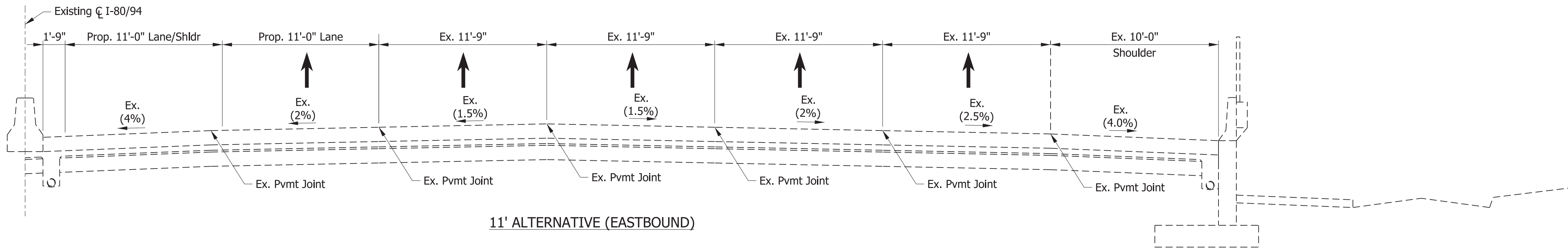
CHECKED: ______ CHECKED: ______

INDIANA
DEPARTMENT OF TRANSPORTATION

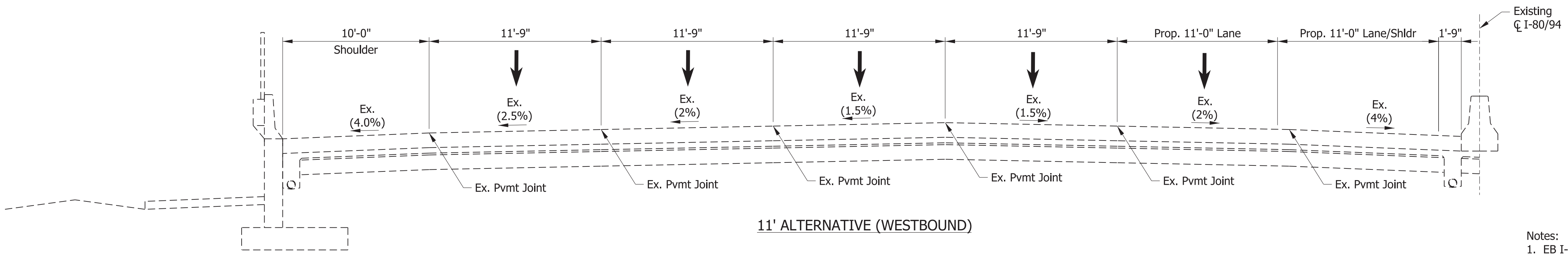
EXISTING KEY MAP

HORIZONTAL SCALE	BRIDGE FILE
N/A	
VERTICAL SCALE	DESIGNATION
N/A	
SURVEY BOOK	SHEETS
ELECTRONIC	of
CONTRACT	PROJECT

IP_PWP:dms50714\Borman TSMO_RD_Sht_Exhibit_Plan_01.dgn

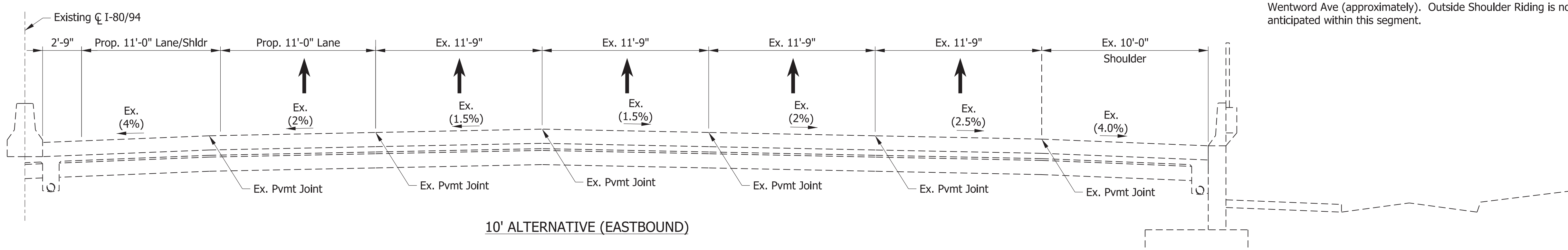


11' ALTERNATIVE (EASTBOUND)

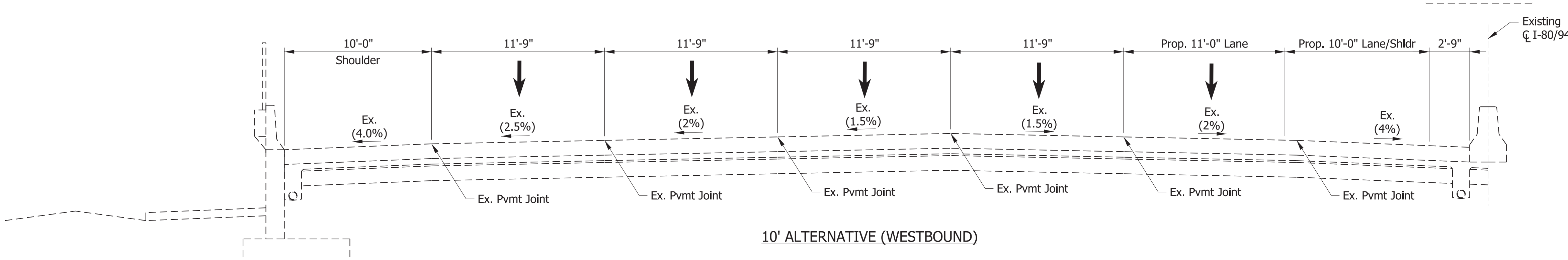


11' ALTERNATIVE (WESTBOUND)

Notes:
1. EB I-80/94 Inside Shoulder Riding is anticipated to occur between I-80/94 over Chicago Ave (approximately) to the Indiana/Illinois State line. Outside Shoulder Riding is not anticipated within this segment.
2. WB I-80/94 Inside Shoulder Riding is anticipated to occur between Indiana/Illinois State line and I-80/94 under Wentword Ave (approximately). Outside Shoulder Riding is not anticipated within this segment.



10' ALTERNATIVE (EASTBOUND)



10' ALTERNATIVE (WESTBOUND)

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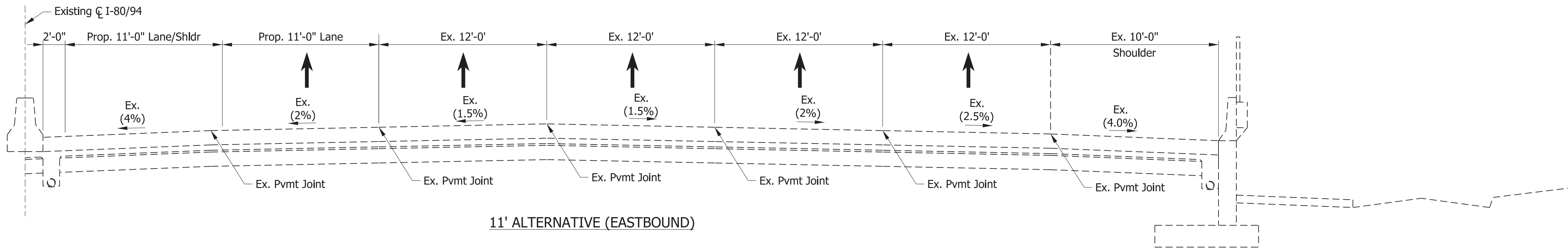
INDIANA
DEPARTMENT OF TRANSPORTATION

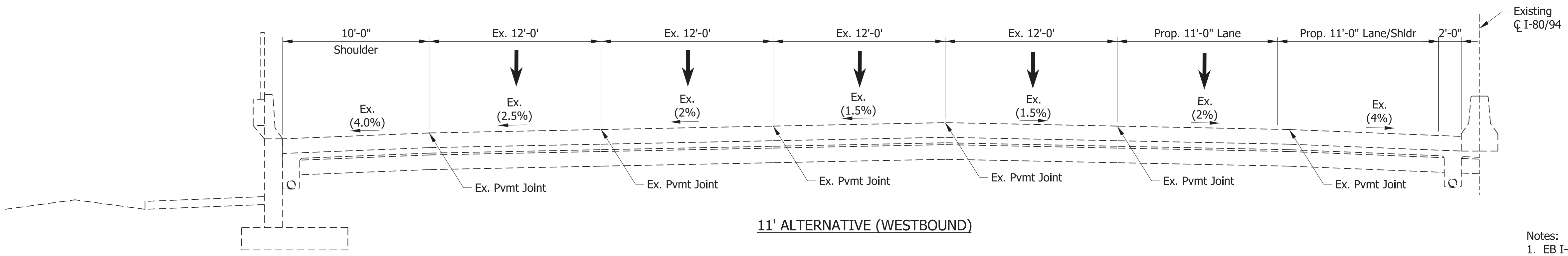
TYPICAL SECTIONS
SHOULDER RIDING LANE
SEGMENTS A

HORIZONTAL SCALE	BRIDGE FILE
1" = 4'	
VERTICAL SCALE	DESIGNATION
1" = 4'	
SURVEY BOOK	SHEETS
ELECTRONIC	of
CONTRACT	PROJECT

IP_PWP:dms50714\Borman TSMO_RD_Sht_Typ_A_Alt.dgn



11' ALTERNATIVE (EASTBOUND)



11' ALTERNATIVE (WESTBOUND)

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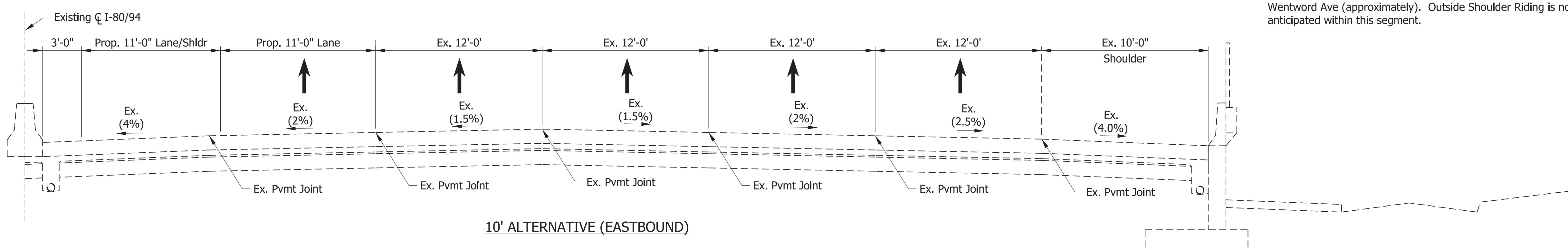
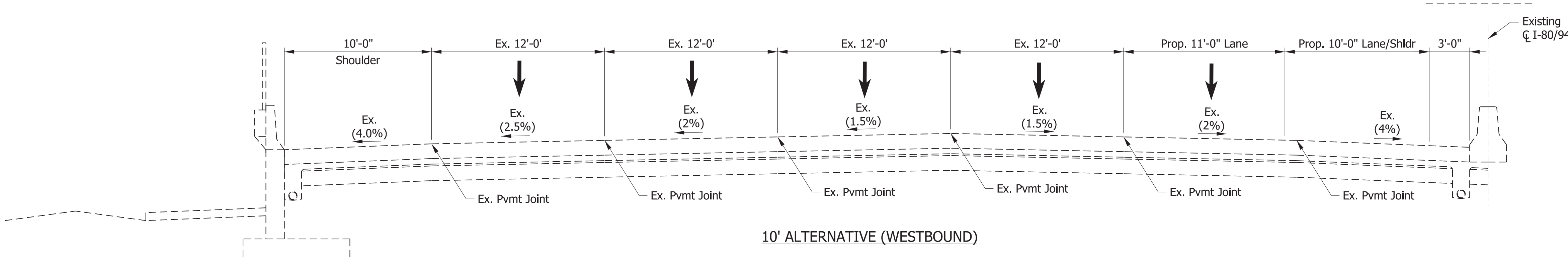


10' ALTERNATIVE (EASTBOUND)



10' ALTERNATIVE (WESTBOUND)

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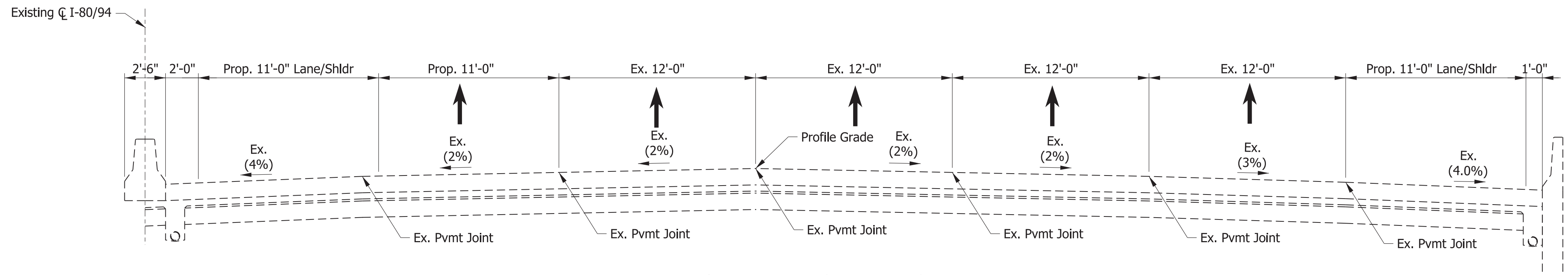
INDIANA
DEPARTMENT OF TRANSPORTATION

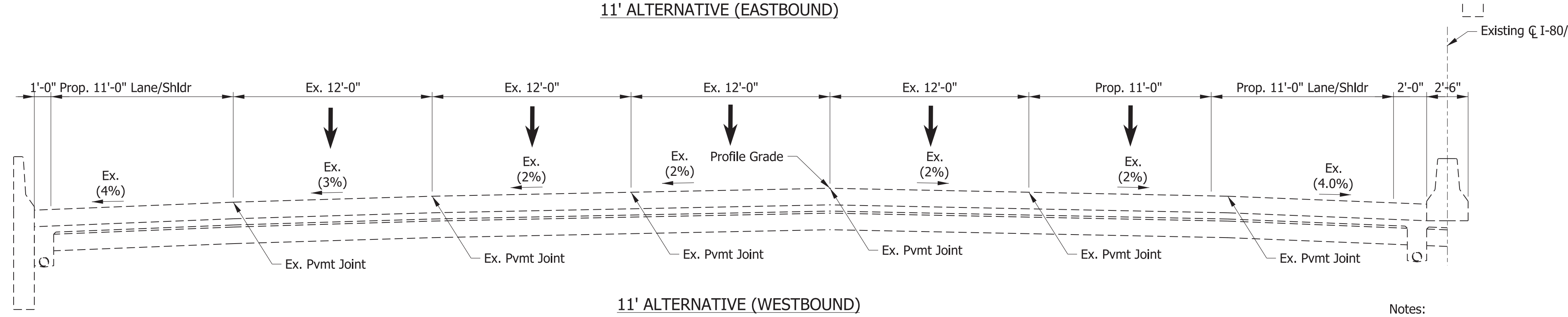
TYPICAL SECTIONS
SHOULDER RIDING LANE
SEGEMENT B

HORIZONTAL SCALE	BRIDGE FILE
1" = 4'	
VERTICAL SCALE	DESIGNATION
1" = 4'	
SURVEY BOOK	SHEETS
ELECTRONIC	of
CONTRACT	PROJECT

IP_PWP:dms50714\Borman TSMO_RD_Sht_Typ_B_Alt.dgn



11' ALTERNATIVE (EASTBOUND)



11' ALTERNATIVE (WESTBOUND)

Notes:
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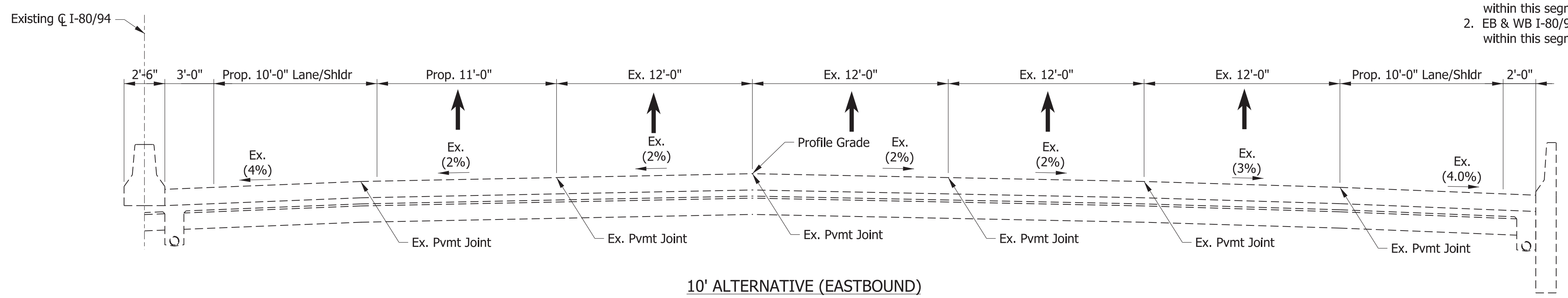
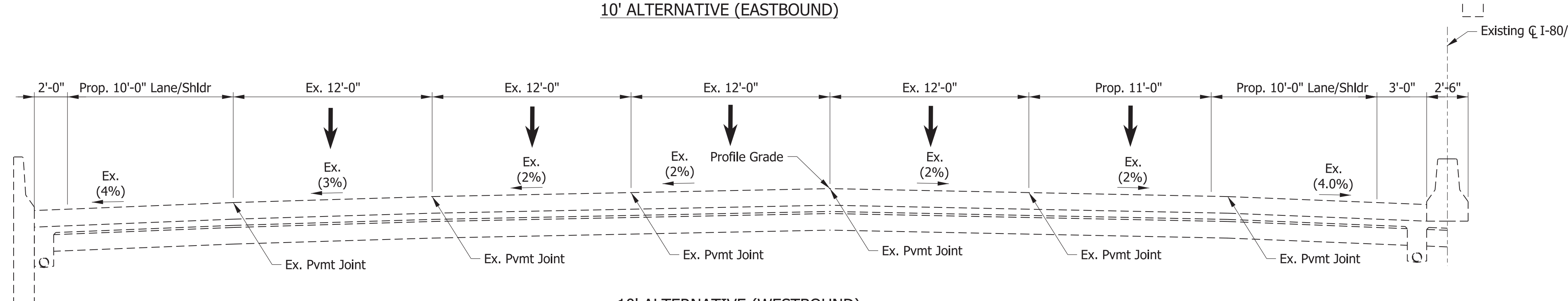
2. EB & WB I-80/94 Outside Shoulder Riding is anticipated to occur within this segment.



10' ALTERNATIVE (EASTBOUND)



10' ALTERNATIVE (WESTBOUND)

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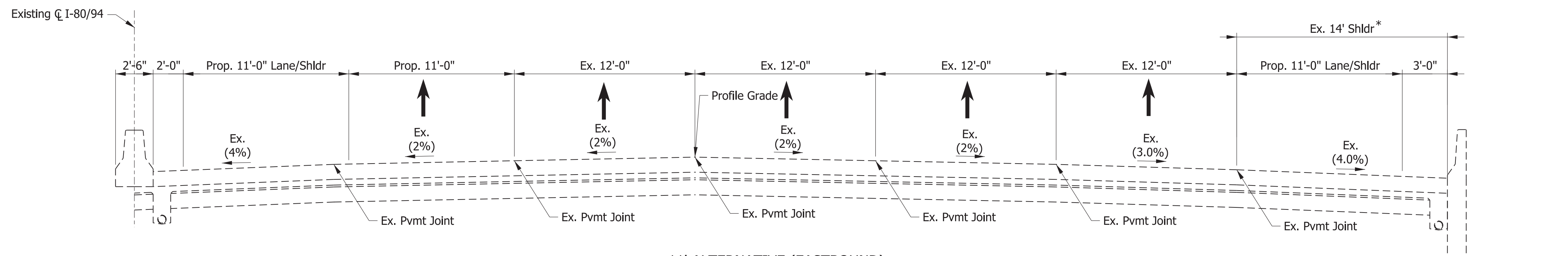
CHECKED: ______ CHECKED: ______

INDIANA
DEPARTMENT OF TRANSPORTATION

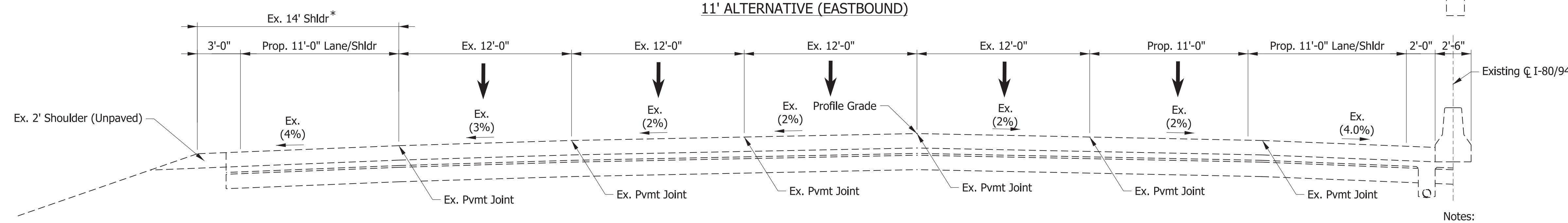
TYPICAL SECTIONS
SHOULDER RIDING LANE
SEGMENT C

HORIZONTAL SCALE	BRIDGE FILE
1" = 4'	
VERTICAL SCALE	DESIGNATION
1" = 4'	
SURVEY BOOK	SHEETS
ELECTRONIC	of
CONTRACT	PROJECT

IP_PWP:dms50714\Borman TSMO_RD_Sht_Typ_C_Alt.dgn



11' ALTERNATIVE (EASTBOUND)



11' ALTERNATIVE (WESTBOUND)

Notes:

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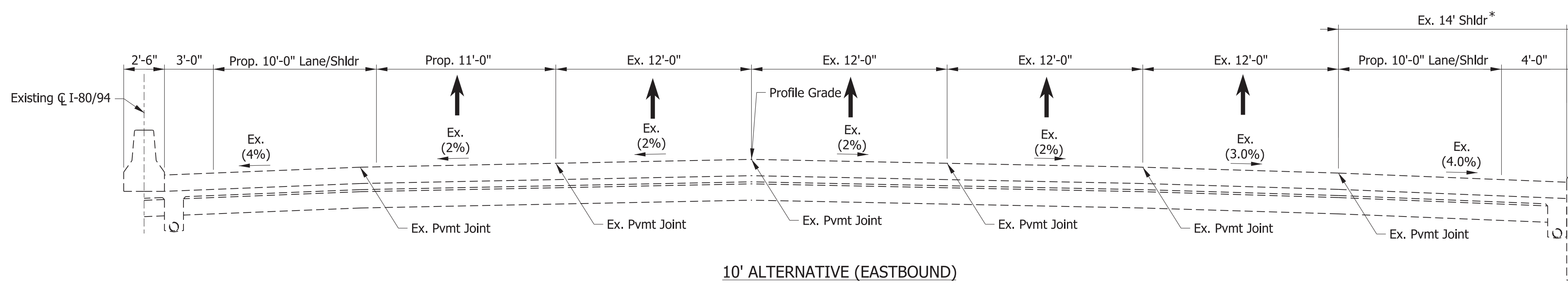
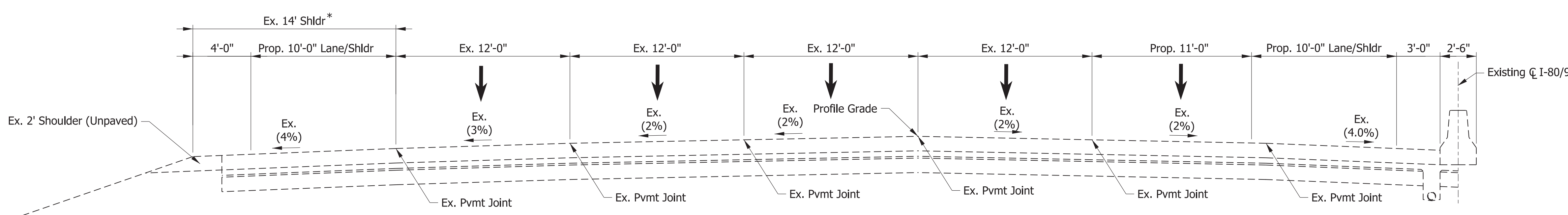
2. EB & WB I-80/94 Outside Shoulder Riding is anticipated to occur within this segment.

* There are locations of Ex. fill slope and Ex. barrier along outside shoulder through the segment. The typical section is to represent the proposed for each situation, and not indicate the entire segment is barrier protected for eastbound and fill slope on the westbound.



10' ALTERNATIVE (EASTBOUND)



10' ALTERNATIVE (WESTBOUND)

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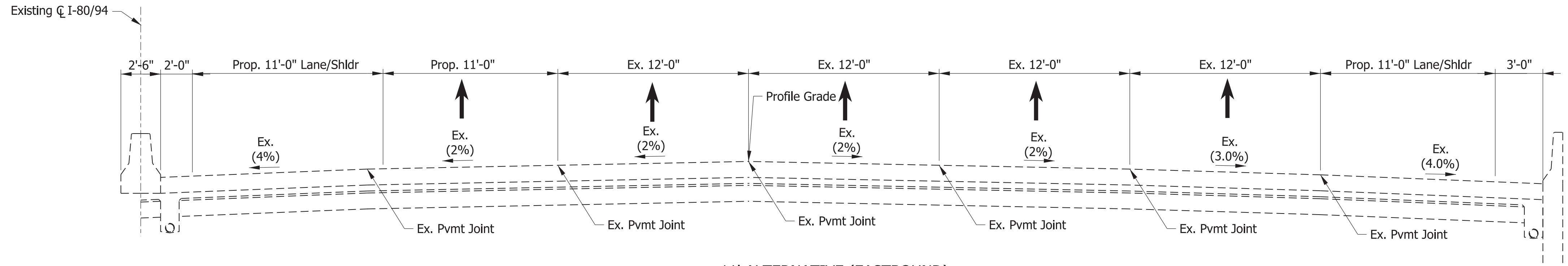
INDIANA
DEPARTMENT OF TRANSPORTATION

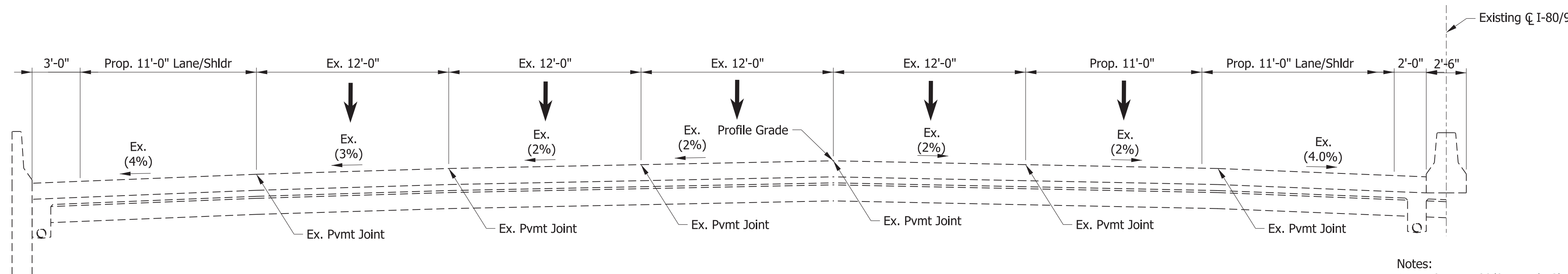
TYPICAL SECTIONS
SHOULDER RIDING LANE
SEGMENT D & F

HORIZONTAL SCALE	BRIDGE FILE
1" = 4'	
VERTICAL SCALE	DESIGNATION
1" = 4'	
SURVEY BOOK	SHEETS
ELECTRONIC	of
CONTRACT	PROJECT

IP_PWP:dms50714\Borman TSMO_RD_Sht_Typ_D&F_Alt.dgn



11' ALTERNATIVE (EASTBOUND)



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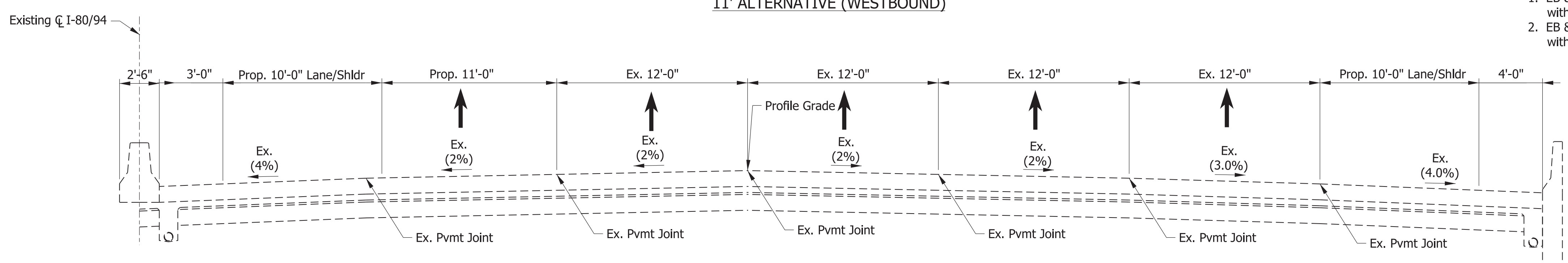
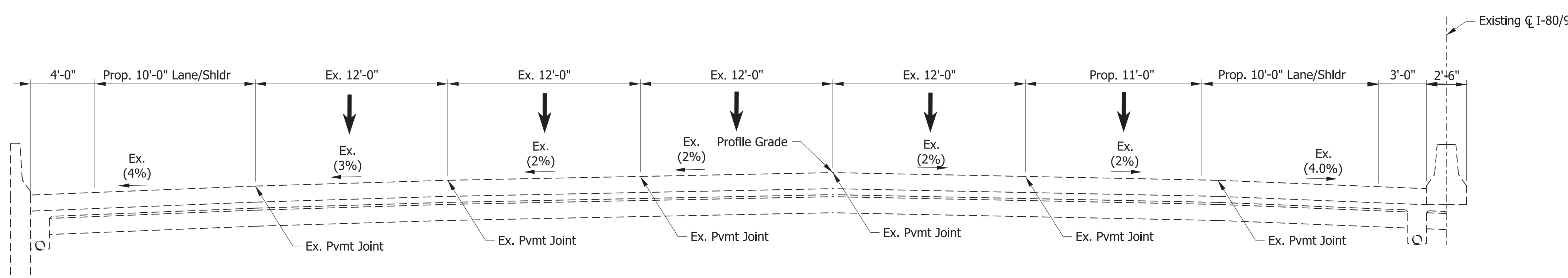


10' ALTERNATIVE (EASTBOUND)



10' ALTERNATIVE (WESTBOUND)

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INDIANA
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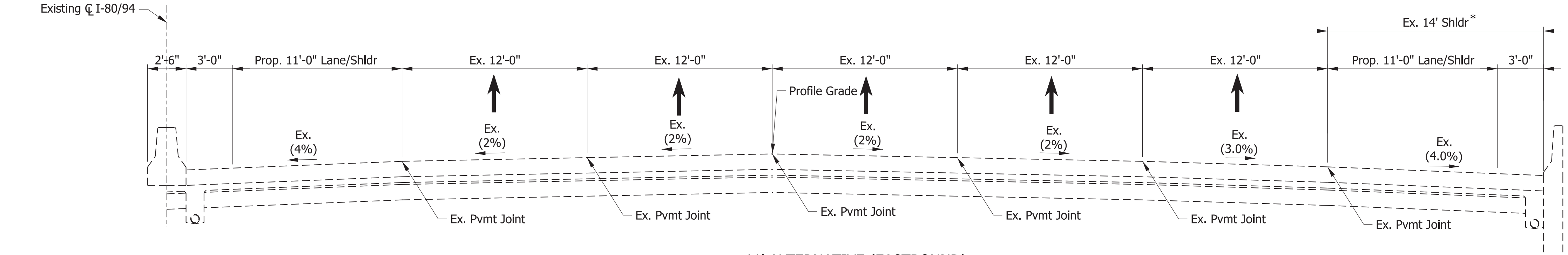
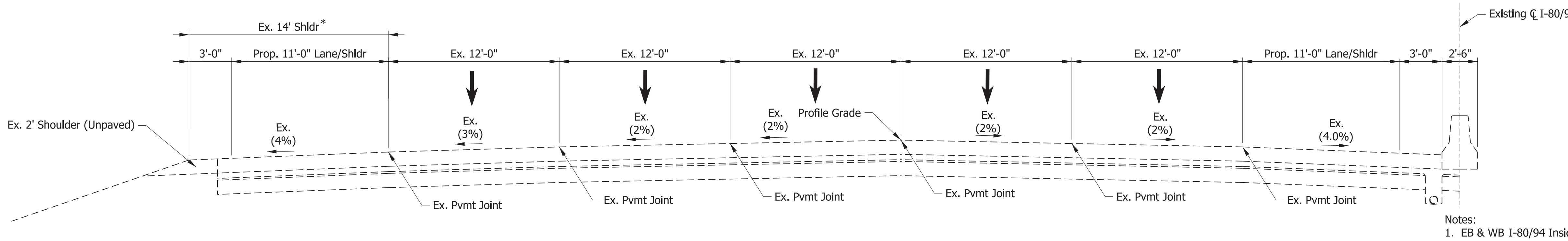
TYPICAL SECTIONS
SHOULDER RIDING LANE
SEGMENT E

HORIZONTAL SCALE	BRIDGE FILE
1" = 4'	
VERTICAL SCALE	DESIGNATION
1" = 4'	
SURVEY BOOK	SHEETS
ELECTRONIC	of
CONTRACT	PROJECT

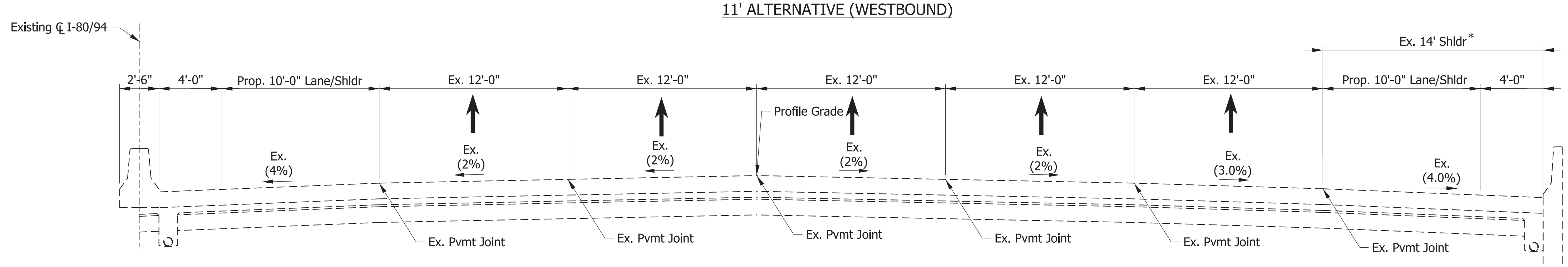
IP_PWP:dms50714\Borman TSMO_RD_Sht_Typ_E'.dgn



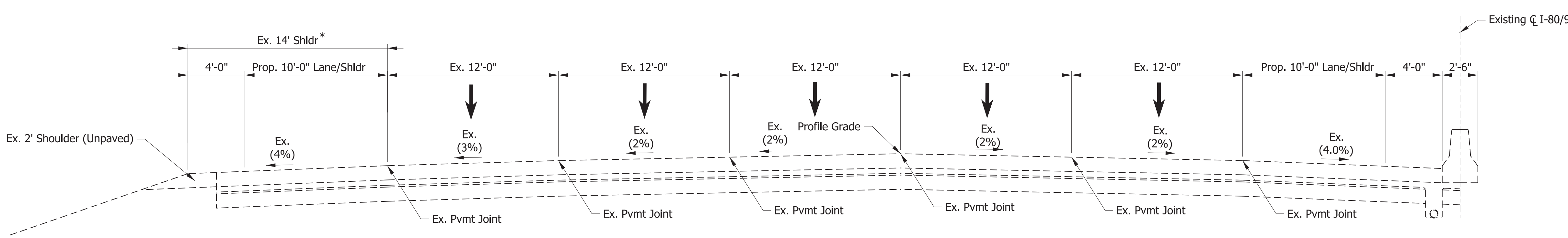
11' ALTERNATIVE (EASTBOUND)



11' ALTERNATIVE (WESTBOUND)



10' ALTERNATIVE (EASTBOUND)



10' ALTERNATIVE (WESTBOUND)

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INDIANA
DEPARTMENT OF TRANSPORTATION

TYPICAL SECTIONS
SHOULDER RIDING LANE
SEGMENT G

HORIZONTAL SCALE	BRIDGE FILE
1" = 4'	
VERTICAL SCALE	DESIGNATION
1" = 4'	
SURVEY BOOK	SHEETS
ELECTRONIC	of
CONTRACT	PROJECT

IP_PWP:dms50714\Borman TSMO_RD_Sht_Typ_G_Alt'.dgn

Appendix B: Consolidated Cost Estimate

Preliminary High Level Cost Estimate Summary

The cost estimates provided in the document are preliminary and are subject to change based on the specific design, system and operational details that are developed during the detailed design phase. These cost estimates are intended to provide an understanding of the order of magnitude of the costs associated with each strategy to help prioritize strategies when weighing costs against potential benefits.

TSMO STRATEGIES	
HARD SHOULDER RUNNING AND LANE CONTROL	**$28,758,284**
RECOMMENDED CIVIL MITIGATION	
GANTRY STRUCTURES AND FOUNDATIONS	
GANTRY EQUIPMENT/CABLING INSTALLATION, INTEGRATION, TESTING	
LANE CONTROL SIGNS	
SMALL MOUNTED DMS ON GANTRY ENDS (roughly 6'x8') 2 per gantry	
GANTRY MOUNTED CCTV CAMERAS	
CABINETS, HANDHOLES, POWER SERVICE, COMMUNICATIONS	
CENTRAL ATM (HSR, LC, VSL, QUEUE WARNING) SOFTWARE	
COMMUNICATIONS REDUNDANCY AND PROTECTION OF EXISTING EQUIPMENT	
QUEUE WARNING	**$940,000**
SMALL MOUNTED DMS ON GANTRY ENDS (roughly 6'x8') 2 per gantry	
GANTRY MOUNTED MICROWAVE RADAR DETECTOR	
CENTER TO CENTER INTEGRATION	
VARIABLE SPEED LIMITS	**$5,413,928**
VARIABLE SPEED LIMIT SIGNS	
MICROWAVE RADAR DETECTOR	
CABINETS, HANDHOLES, POWER SERVICE, COMMUNICATIONS	
RAMP METERING	**$2,009,646**
RAMP METERING EQUIPMENT, POWER, AND COMMUNICATIONS	
INTEGRATION AND TESTING	
RAMP METERING CONTROL SOFTWARE	
MOBILIZATION/DEMOBILIZATION, MAINTENANCE AND PROTECTION OF TRAFFIC	**$550,000**
TOTAL	**$40,288,020**

OTHER POTENTIAL TSMO OPTIONS	
SPECIAL PURPOSE LANE SIGNING	$80,000
WORK ZONE MANAGEMENT SOFTWARE	$50,000
ROAD WEATHER INFORMATION SYSTEMS	$250,000
VSL-QUEUE WARNING INTERFACE	$50,000
OPTIMIZED DATA AND VIDEO SHARING	$50,000
CENTER TO CENTER INTERFACES	$150,000
CAD-ATMS INTEGRATION	$85,000
TOWING AND RECOVERY INCENTIVE PROGRAM	$285,000
GEOMETRIC CHANGES	TBD
GUIDE SIGNS	TBD
ENHANCED HOOSIER HELPER PROGRAM	TBD
WINTER ROADWAY OPERATIONS CHANGES	TBD
AUGMENTED ROAD RAKING AND SWEEPING FOR DEBRIS	TBD
90-DAY ENHANCED LAW ENFORCEMENT AT OPENING	TBD
TOTAL	**$1,000,000**

OPTIONAL CIVIL MITIGATION DRAINAGE IMPROVEMENTS RETROFIT LOAD TRANSFER BARS	**$36,100,000**

ILLINOIS DEPLOYMENT	
HARD SHOULDER RUNNING AND LANE CONTROL	$2,229,262
QUEUE WARNING	$56,000
VARIABLE SPEED LIMITS	$105,300
LUMP SUM (MOT, Design, Construction Engineering, etc.)	$812,000
CENTER TO CENTER INTERFACE	$300,000
TOTAL	**$3,502,562**
OPTIONAL CIVIL MITIGATION	$2,466,293
CONTINGENCY (10%)	$596,885

References

[i] https://ops.fhwa.dot.gov/tsmo/#q1

[ii] https://ops.fhwa.dot.gov/tsmo/#q1

[iii] https://ops.fhwa.dot.gov/tsmo/#q4

[iv] https://ops.fhwa.dot.gov/freewaymgmt/ramp_metering/about.htm

[v] https://ops.fhwa.dot.gov/publications/managelanes_primer/