FLEX ROAD

LESS STOP, MORE GO

I-80/94 BORMAN EXPRESSWAY

Transportation Systems Management and Operations (TSMO)

Alternative Assessment Report

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INDIANA DEPARTMENT OF TRANSPORTATION

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Section 1 – INTRODUCTION

The I-80/94 FlexRoad Planning and Environment Linkages (PEL) Study seeks to improve the mobility, safety, and reliability of the study corridor through the potential deployment of one or more Transportation Systems Management and Operations (TSMO) strategies. The study area includes the I-80/94 corridor from I-65 in Indiana on the east to IL 394 in Illinois on the west. The Indiana portion of the corridor is called the Borman Expressway and is a critical interstate link between the Chicago area and points east.

The I-80/94 freeway is predominantly an eight-lane facility with four continuous general purpose lanes in each direction. The average annual daily traffic (AADT) ranges from 204,000 vehicles at the state line to 158,000 vehicles at I-65. The corridor is a heavily used truck corridor with trucks comprising up to 31 percent of the daily traffic and up to 25 percent of peak-hour traffic. The corridor serves as both a connector for the local communities as well as a through-corridor for more regional trips. Origin-destination data shows that 60 percent of westbound and 44 percent of eastbound PM peak-period trips are through trips.

Traffic volumes throughout the corridor are forecasted to increase by 2040, the design year of the study, exacerbating these issues. Peak-period traffic is expected to increase by up to 18 percent. The design year reflects a recognition that improvements that would address the corridor issues 20-30 years into the future are likely beyond the states' available funding and would likely result in significant right-of-way and environmental impacts. Neither the Indiana Department of Transportation (INDOT) nor the Northwest Indiana Regional Planning Commission (NIRPC) long range planning documents identify funds for significant expansion in the corridor.

1.1 STUDY TERMINI

The limits of the study have been defined based on the identified needs in the corridor. The study will evaluate improvements to I-80/94 from IL 394 in Illinois to I-65 in Indiana as graphically shown in **Figure 1.1**. East-west traffic in this area of the Midwest have several options east and west of Lake Michigan. However, to travel around the south end of Lake Michigan, all the major routes "funnel" into two main interstate corridors: I-80/94 and I-90 (tolled). The two termini identified provide natural breaks in the consistent facility in between the two system interchanges forming the terminus points. At the western terminus, the I-80/94 corridor splits to the west on I-80/I-294 (tolled), to the south on IL 394, and to the north on I-94. At the eastern terminus at I-65, the I-80/94 corridor splits to the south on I-65 and further to the east via I-94 and I-80/90 (tolled).

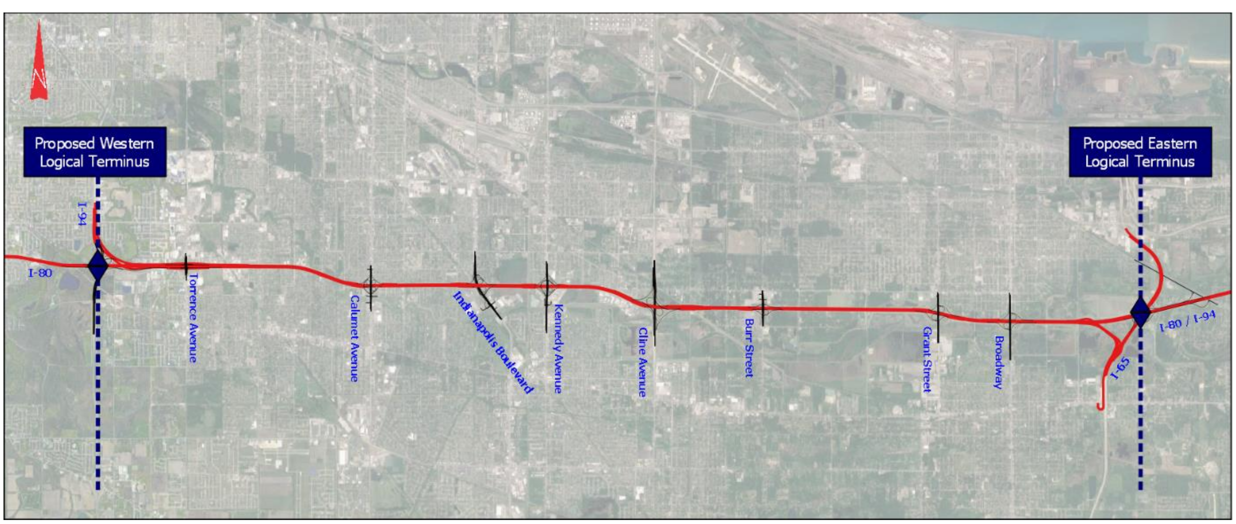


Figure 1.1: Proposed Logical Termini

Congestion and safety concerns likely extend beyond the study termini, but this roadway segment is consistent in character (lane configuration, interchange spacing, development patterns, etc.) and the severity of the issues within these limits is higher. The traffic volumes decrease significantly beyond these termini. Further, beyond the west terminus, the roadway leaves the jurisdiction of IDOT and is the responsibility of the Illinois State Toll Highway Authority, an independent toll authority with its own congestion management programs. Beyond the east terminus, the roadway continues to be under the jurisdiction of INDOT.

Depending on the strategies considered, physical improvements may be required in the immediate vicinity of one or more of the ten interchanges within the I-80/94 study corridor. Also, upstream messaging may be necessary on the aforementioned roadways on approach to the I-80/94 corridor. For this reason, at the east and west termini, the actual study area will extend to the next interchange in each direction, and at the intermediate interchanges between the terminus points, the study area will extend a minimum of approximately 1,000 feet to the north and south along the intersecting roadway.

1.2 PURPOSE AND NEED

The need for this study is based on recurring corridor congestion and elevated crash rates on I-80/94 between IL 394 in Cook County, Illinois and I-65 in Lake County, Indiana. Motorists within this corridor experience recurring congestion during weekday peak commuting periods and on Sunday afternoons/evenings, especially during the summer season. The presence of congestion along the corridor results in poor travel time reliability and low speeds during peak hours. The Northwest Indiana Regional Planning Commission (NIRPC) has identified this roadway as the most congested interstate highway corridor in northwest Indiana.

Two primary needs have been identified for the 80/94 FlexRoad study:

- Recurring traffic congestion – bottleneck locations that result in travel time delays, low travel speeds, and unacceptable levels of service.
- Safety –segments of high crash rates in the corridor.

Based on the primary needs, the purpose of this study is to identify corridor improvements that, based on the design year of 2040, will:

- Increase the operational efficiency of the corridor by reducing travel times and increasing travel time reliability.
- Improve safety in the corridor by reducing crashes.

As a principle, alternatives should focus on cost-effectively addressing the study needs within the existing infrastructure based on anticipated funding and right-of-way constraints.

1.3 REPORT ORGANIZATION

This document has been prepared to summarize the assessment of the various TSMO strategies being considered for the I-80/94 corridor to mitigate the effects of the recurring corridor congestion and the elevated crash rates. The findings of the assessment include technical information to assist in the prioritization of the TSMO strategies and identification of alternative packages of complementary TSMO strategies for additional analysis in the next phase of the study.

To provide a comprehensive summary of the study process, the document specifically provides an overview of the study corridor characteristics, the existing and future corridor conditions, a description of the TSMO strategies that are considered relevant for the corridor, a summary of the assessment of each TSMO strategy in accordance with a set of key performance indicators and costs, and the identification of alternative packages of complementary TSMO strategies.

Section 2 – STUDY CORRIDOR

This section provides a brief overview of the study corridor including a description of both the physical and traffic characteristics of the freeway.

2.1 PHYSICAL CHARACTERISTICS

This overview includes the general cross section within the study areas, posted speed, freeway geometry, and connectivity to the adjacent road network and other interstate facilities.

2.1.1 Freeway Cross Section

With the study limits, I-80/94 is predominantly an eight-lane facility, with four (4) continuous general purpose lanes in each direction, separated by a concrete median barrier. At least one auxiliary lane is provided between all interchanges, thus creating segments with a cross section consisting of five (5) lanes in each direction for a large portion of the freeway length. There are no significant width constraints along the corridor to impact traffic operations as shoulders, ranging from 10 feet to 14 feet, are provided on both the inside and outside of the freeway lanes.

2.1.2 Posted Speed

The posted speed limit is 55 miles per hour (mph) through the entire length of the corridor in both Indiana and Illinois.

2.1.3 Freeway Geometry

The horizontal geometry of the freeway facility is generally straight with two large radius S-curves located between long tangent sections west of Calumet Avenue and again west of Cline Avenue. The vertical geometry is relatively flat, with no significant grades that would affect traffic operations.

2.1.4 Freeway Connections

With respect to connections or junctions, there are two system interchanges and eight service interchanges within the study limits, as shown in **Figure 2.1**. The system interchanges are:

- I-294/I-94/IL 394, located at the western limits of the study corridor
- I-65, located at the eastern limits of the study corridor

The service interchanges are identified as follows:

- Torrence Avenue/US 6/IL 83
- Calumet Avenue/US 41
- Indianapolis Boulevard/SR 152
- Kennedy Avenue
- Cline Avenue/SR 912
- Burr Street
- Grant Street
- Broadway/SR 53

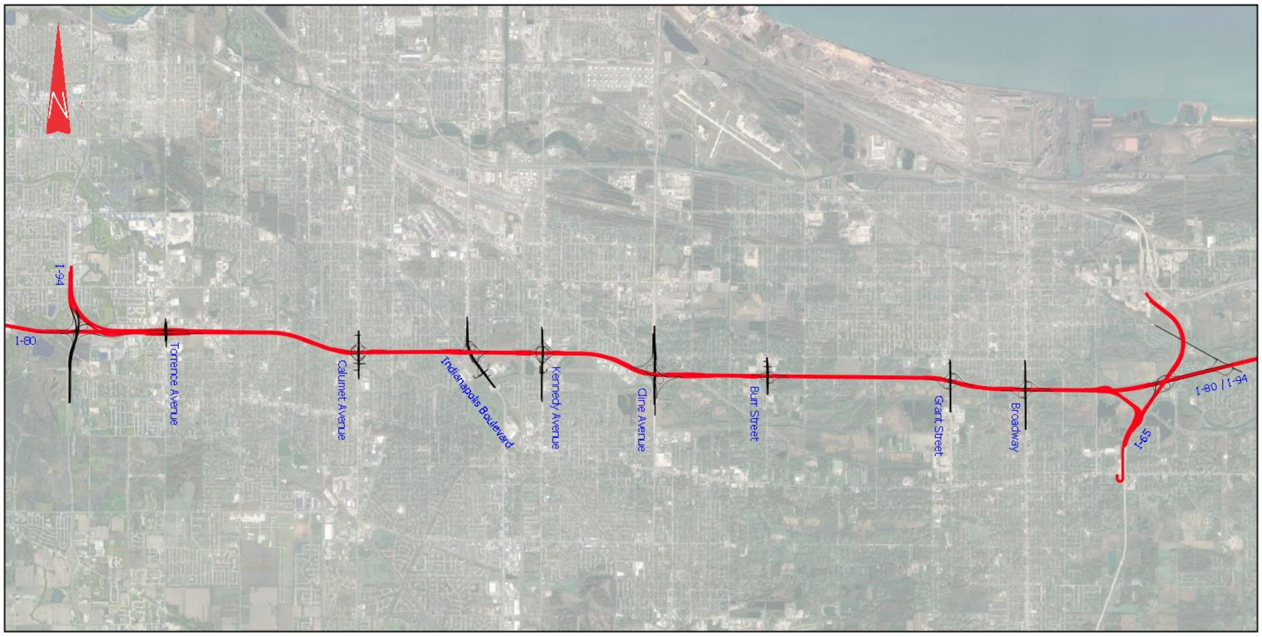


Figure 2.1: I-80/94 Corridor – Interchange Locations

A brief description of each interchange configuration, from west to east, is provided below.

I-294/I-94/IL 394 System Interchange

The I-294/I-94/IL 394 interchange is a semi-directional interchange located in close proximity with the Torrence Avenue (US 6/IL 83) interchange to the east in Illinois. All freeway-to-freeway movements are accommodated by directional ramps except the IL 394 northbound to I-294 westbound movement, which is accommodated by a loop ramp. A collector-distributor lane system is provided between the I-294/I-94/IL 394 and Torrence Avenue (US 6/IL 83) interchanges, with the Torrence Avenue ramps "nested" between the collector distributor lanes.

Specifically, the IL 394 northbound to I-80/94 eastbound movement is accommodated via the collector-distributor lanes, which merges with the Torrence Avenue eastbound entrance ramp movement before merging with the mainline east of the Torrence Avenue (US 6/IL 83) interchange. Similarly, the I-80/94 westbound to I-94 northbound movement is accommodated by the collector-distributor lanes that begin east of the Torrence Avenue (US 6/IL 83) interchange, which merge with the Torrence Avenue westbound entrance ramp movement before merging with the I-94 northbound mainline. The I-80/94 westbound to IL 394 southbound movement is also accommodated by the westbound collector-distributor lanes, as well as the directional ramp located downstream of the Torrence Avenue westbound entrance ramp, before merging with the IL 394 southbound mainline. In contrast, the I-94 southbound to I-94 eastbound movement is accommodated via a directional ramp that merges with the mainline west of Torrence Avenue, without using the eastbound collector-distributor lanes.

Torrence Avenue (US 6/IL 83) Service Interchange

The Torrence Avenue (US 6/IL 83) interchange is a single-point diamond interchange located in close proximity to the I-94 (I-294/IL 394) interchange to the west. As described above, the Torrence Avenue interchange is "nested" within the collector-distributor lane system that carries I-94 from the east to the north.

Specifically, the Torrence Avenue eastbound exit ramp merges with the IL 394 northbound to I-94 eastbound ramp, and subsequently with the I-94 southbound to Torrence Avenue exit ramp, before exiting to Torrence Avenue. The Torrence Avenue eastbound entrance ramp movement also merges with the IL 394 northbound and I-94 southbound traffic before merging with the I-94 eastbound mainline. In the westbound direction, the Torrence Avenue westbound entrance ramp merges with the I-80 westbound to I-94 northbound/IL 394 southbound movement before merging with the I-80 westbound mainline.

Calumet Avenue (US 41) Service Interchange

The Calumet Avenue interchange is a partial cloverleaf interchange, located east of the Illinois/Indiana state line. All left-turn movements are accommodated by the loop ramps in the three quadrants, except for the Calumet Avenue southbound to I-80/94 eastbound movement, which is accommodated by a semi-direct connection. The eastbound entrance ramps from northbound Calumet Avenue and southbound US 41 merge to form one entrance ramp to the I-80/94 mainline, which becomes an auxiliary lane extending to the Indianapolis Boulevard interchange. The westbound entrance ramps from northbound Calumet Avenue and southbound US 41 merge to form one entrance ramp to the I-80/94 mainline, which becomes an auxiliary lane to the Torrence Avenue (US 6/IL 83) interchange.

A single exit ramp, configured as an extended auxiliary lane from the upstream interchange, is provided in the westbound direction and subsequently diverges to provide access to both the north and south directions of Calumet Avenue. A similar configuration is provided in the eastbound direction, with only a single ramp exiting the I-80/94 mainline.

Indianapolis Boulevard (US 41) Service Interchange

The Indianapolis Boulevard interchange is a modified partial cloverleaf (ParClo AB) interchange with semi-direct connections for the I-80/94 westbound to Indianapolis Boulevard (US 41) southbound movement, as well as the Indianapolis Boulevard southbound to I-94 eastbound movement. The eastbound entrance ramps from northbound US 41 and southbound Indianapolis Boulevard merge to form one entrance ramp to the I-80/94 mainline, which becomes an auxiliary lane extending to the Kennedy Avenue interchange. The westbound on-ramps from northbound US 41 and southbound Calumet Avenue merge to form one entrance ramp to the I-80/94 mainline, which becomes an auxiliary lane extending to the Calumet Avenue interchange.

A single exit with two lanes, the second lane developed through a short 600 foot parallel lane section to the extended auxiliary lane from the upstream interchange, is provided in the westbound direction and subsequently splits into two single lane ramps to provide access to both the north and south directions of Indianapolis Boulevard (US 41). In the eastbound direction, only a single ramp exiting the I-80/94 mainline is provided and configured as an extended auxiliary lane from the upstream interchange.

Kennedy Avenue Service Interchange

The Kennedy Avenue interchange is a modified partial cloverleaf (ParClo – AB) interchange with semi-direct connections for the I-80/94 westbound to Kennedy Avenue southbound movement, as well as the Kennedy Avenue southbound to I-80/94 eastbound movement. The eastbound entrance ramps from northbound and southbound Kennedy Avenue merge to form one entrance ramp to the I-80/94 mainline, which becomes an auxiliary lane extending to the Cline Avenue (SR 912) interchange. The westbound entrance ramps from northbound and southbound Kennedy Avenue merge to form one entrance ramp to the I-80/94 mainline, which becomes an auxiliary lane extending to the Indianapolis Boulevard (US 41) interchange.

A single exit ramp, configured as an extended auxiliary lane from the upstream interchange, is provided in the westbound direction and subsequently diverges to provide access to both the north and south directions of

Kennedy Avenue. A similar configuration is provided in the eastbound direction, with only a single ramp exiting the I-80/94 mainline.

Cline Avenue (SR 912) Service Interchange

The Cline Avenue interchange is a partial cloverleaf (ParClo B) interchange with directional ramps provided for the southbound SR 912 to eastbound I-80/94 movement, as well as the northbound Cline Avenue to westbound I-80/94 westbound movement. Loop ramps are provided for the I-94 eastbound to Cline Avenue (SR 912) northbound movement, as well as the I-80/94 westbound to Cline Avenue southbound movement. The eastbound entrance ramps from northbound Cline Avenue and southbound SR 912 merge to form one entrance ramp to the I-80/94 mainline, which becomes an auxiliary lane extending to the Burr Street interchange. The westbound entrance ramps from northbound Cline Avenue and southbound SR 912 merge to form one entrance ramp to the I-80/94 mainline, which becomes an auxiliary lane extending to the Kennedy Avenue interchange.

A single exit ramp, configured as an extended auxiliary lane from the upstream interchange, is provided in the westbound direction and subsequently diverges to provide access to both the north and south directions of Cline Avenue. A similar configuration is provided in the eastbound direction, with only a single ramp exiting the I-80/94 mainline.

Burr Street Service Interchange

The Burr Street interchange is a modified diamond interchange with single entrance ramps for both the eastbound and westbound directions. The I-80/94 eastbound to Burr Street northbound movement is accommodated by a loop ramp. The eastbound entrance ramp serving access from both northbound and southbound Burr Street forms one entrance ramp to the I-80/94 mainline, which becomes an auxiliary lane extending to the Grant Street interchange. The westbound entrance ramp serving northbound and southbound Burr Street forms one entrance ramp to the I-80/94 mainline, which becomes an auxiliary lane extending to the Cline Avenue (SR 912) interchange.

A single exit ramp, configured as an extended auxiliary lane from the upstream interchange, is provided in the westbound direction and subsequently diverges to provide access to both the north and south directions of Burr Street. A similar configuration is provided in the eastbound direction, with only a single ramp exiting the I-80/I-94 mainline.

Both ramp terminal intersections are signalized, with the south ramp terminal configured as a “T” intersection noting that the eastbound to northbound left turn movement is accommodated in the loop ramp.

Grant Street Service Interchange

The Grant Street interchange is a typical partial cloverleaf (ParClo A) interchange, with the left-turn movements from Grant Street to the freeway accommodated by loop ramps. The eastbound entrance ramps providing access from northbound and southbound Grant Street, merge to form one entrance ramp to the I-80/94 mainline, which becomes an auxiliary lane extending to the Broadway (SR 53) interchange. The westbound entrance ramps providing access from both northbound and southbound Grant Street, merge to form one entrance ramp to the I-80/94 mainline, which becomes an auxiliary lane, extending to the Burr Street interchange.

A single exit ramp, configured as an extended auxiliary lane from the upstream interchange, is provided in the westbound direction and connects to Burr Street at a signalized intersection, with a channelized right turn movement. A similar configuration is provided in the eastbound direction, with only a single ramp exiting the

I-80/94 mainline and connecting to Burr Street at a signalized intersection with a channelized right turn movement.

Broadway/SR 53 Service Interchange

The Broadway interchange is a typical partial cloverleaf (ParClo A) interchange, with the left-turn movements from Broadway (SR 53) to the freeway accommodated by loop ramps. The eastbound entrance ramps providing access from both northbound and southbound Broadway merge to form one entrance ramp to the I80/I-94 mainline, which becomes an auxiliary lane extending to the I-65 interchange. The westbound entranced ramps providing access from both northbound and southbound Broadway merge to form one entrance ramp to the I-80/94 mainline, which becomes an auxiliary lane extending to the Grant Street interchange.

A single exit ramp, configured as an extended auxiliary lane from the upstream interchange, is provided in the westbound direction and connects to Broadway at a signalized intersection, with a channelized right turn movement. A similar configuration is provided in the eastbound direction, with only a single ramp exiting the I-80/I-94 mainline and connecting to Broadway at a signalized intersection with a channelized right turn movement.

I-65 System Interchange

The I-65 freeway connects with the I-80/94 corridor via two interchanges. The western interchange is a y type three-legged interchange that provides connections with I-65 south of the corridor. This interchange accommodates the I-80/94 eastbound to I-65 southbound movement, as well as the I-65 northbound to I-80/94 westbound movement.

The eastern interchange is a partial cloverleaf interchange (Parclo AB) that provides connections with I-65 north of the corridor. Loop ramps are provided for the I-80/94 eastbound to I-65 northbound movement, as well as the I-65 southbound to I-80/94 eastbound movement. A semi-direct connection is provided for the I-80/94 westbound to I-65 southbound movement.

A collector-distributor road system is provided between I-65 north and Central Avenue. In the eastbound direction, the collector distributor lanes accommodate eastbound movements from I-94 eastbound, I-65 northbound, and I-65 northbound that are destined to I-80/94 eastbound or Central Avenue. In the westbound direction, the collector distributor lanes begin east of Central Avenue and accommodate westbound movements from I-80/94 westbound and Central Avenue that are destined to I-65 northbound, I-65 southbound, and I-80/94 westbound.

2.1.5 Traffic Characteristics – Existing Conditions

An overview of the existing traffic characteristics along the study corridor is presented in this section in terms of traffic volumes and traffic composition. The traffic information presented has been extracted from the traffic operations (microsimulation) models that have been developed specifically for this study. The traffic operations models were calibrated to simulate conditions for the representative weekday AM and PM peak hours in 2019, in order to avoid the impacts associated with the COVID-19 pandemic which affected traffic patterns and volumes in 2020.

2.1.6 Traffic Volumes

The modeled traffic volumes for the study corridor are graphically shown in **Figure A.1** and **Figure A.2**, (see **Appendix A)** for the typical weekday AM and PM peak hour conditions, respectively. The approximate AM peak hour is 7:00 am to 8:00 am whereas the PM peak hour is approximately 4:00 pm to 5:00 pm noting that, given the length of the corridor, the peak hours will differ within the corridor.

Freeway Mainline Traffic Volumes

Mainline segment traffic volumes are summarized in **Table 2.1** below. As the data suggests, the study corridor is heavily traveled during both the typical weekday AM and PM peak periods with traffic volumes exceeding 7000 vph in some segments.

During the typical weekday AM peak hour, the westbound direction is noted with slightly higher traffic flow than the eastbound direction. In contrast, during the typical weekday PM peak hour, the eastbound direction is associated with notably greater traffic flow than the westbound direction. Also, the PM peak hour volumes are higher than the AM peak hour volumes.

Table 2.1: I-80/94 Typical Weekday AM and PM Peak Hour Mainline Segment Traffic Volumes

LOCATION	AM		PM	
	WB (vph)	EB (vph)	WB (vph)	EB (vph)
West of I-94/IL 394	6860	5200	6330	6460
East of I-94/IL 394	4350	3580	4530	4690
East of Torrence Ave/US 6/IL 83	5410	4740	6150	7460
East of Calumet Ave/US 41	5520	4840	6190	7580
East of Indianapolis Blvd/SR 152	5530	5010	6120	7510
East of Kennedy Ave	5410	5000	6100	7270
East of Cline Ave/SR 912	5500	5090	5860	7260
East of Burr St	5290	4980	5900	6790
East of Grant St	5170	4950	5860	6780
East of Broadway/SR 53	5010	4780	5520	6520
East of I-65	3560	3130	3670	3630

Freeway Ramp Traffic Volumes

Freeway ramp traffic volumes are summarized at all interchange locations along the study corridor, as shown in **Table 2.2**, with high entrance and exit ramp volumes (greater than 800 vph) highlighted in red. High ramp volumes are noted at the two system interchanges. In particular, in the eastbound direction, the entrance ramp from I-94 North carries over 2,600 vehicles per hour (vph) during the PM peak hour, and the exit ramp to I-65 South carries over 2,000 vph in the AM peak hour and over 3,200 vph in the PM peak hour. In the westbound direction, the on-ramp from I-65 South carries approximately 2,000 vph during both the AM and PM peak hours, and the exit ramp to I-94 North carries approximately 2,000 vph during the PM peak hour.

High ramp volumes are also noted at the Calumet Avenue/US 41 and Cline Avenue/SR 912 service interchanges, with almost all ramp volumes being greater than 800 vehicles during both the AM and PM peak hours.

Table 2.2: I-80/94 Typical AM and PM Weekday Peak Hour Ramp Traffic Volumes (2019)

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	1570 980	1090	1250 210	1610	800 1020	1960	2610 720	1740
Torrence Avenue	560	520	260	530	930	570	680	1340
Calumet Ave/US 41	920	1000	870	730	1130	1160	1480	1400
Indianapolis Blvd	720	700	650	470	840	720	1080	1140
Kennedy Avenue	550	420	410	400	530	520	820	970
Cline Avenue	1200	1260	1030	940	1320	1050	1490	1330
Burr Street	470	250	310	400	400	420	380	800
Grant Street	380	210	290	320	470	390	490	510
Broadway/SR 53	470	280	300	460	650	290	640	750
I-65 Interchange	410 1890	820	730	2060 270	620 2040	790	740	3210 430

Note: High volume ramps (greater than 800 vph) are shown in red.

2.1.7 Traffic Composition

Compounding the high traffic volumes is the high number of large trucks within the traffic stream. Currently, trucks are limited to travel on the two rightmost lanes only. The truck lane restriction may affect traffic operations and safety along the corridor, as vehicles must weave among the trucks as they enter or exit the freeway.

Estimates of the average truck percentage on a daily basis for each segment, as obtained from the INDOT Traffic Count Database System (TCDS) and the IDOT traffic information website for the most recent year prior to year 2020 (primarily 2019 to reflect pre-COVID 19 conditions), are shown in **Table 2.3**. On a daily basis, trucks account for as high as 30% of the overall traffic stream in some segments of the study corridor.

Table 2.3: Daily Average Truck Percentages

LOCATION	WB %	EB %
West of I-94/IL 394	N/A	25
East of I-94/IL 394	N/A	N/A
East of Torrence Avenue	26	24
East of Calumet Avenue	31	30
East of Indianapolis Boulevard	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

Modeled typical weekday AM and PM peak hour truck percentages are presented in **Table 2.4.** The truck percentages are generally lower in the PM peak hour than the AM peak hour, though the actual numbers of trucks may be similar given the typically higher overall traffic volumes during the PM peak period.

Table 2.4: Modeled Typical Weekday AM and PM Peak Hour Truck Percentages

LOCATION	AM		PM	
	WB %	EB %	WB %	EB %
West of I-94/IL 394	14	16	13	16
East of I-94/IL 394	22	21	17	21
East of Torrence Avenue	22	22	15	15
East of Calumet Avenue	18	22	15	15
East of Indianapolis Boulevard	18	21	15	15
East of Kennedy Avenue	18	21	15	15
East of Cline Avenue	17	20	16	14
East of Burr Street	18	20	16	15
East of Grant Street	19	20	16	14
East of Broadway	20	21	17	15
East of I-65	24	20	17	16

2.2 TRAFFIC CHARACTERISTICS – FUTURE CONDITIONS

The future traffic volumes used in this study are based on the forecasted traffic demand for the 2040 planning horizon derived from the Northwestern Indiana Regional Planning Commission (NIRPC) travel demand model. This traffic demand was subsequently applied to the Future Base Case traffic operations models which were developed from the calibrated existing conditions traffic operations models.

An overview of the future traffic volumes and vehicle composition anticipated to be using the corridor in the 2040 planning horizon is provided below.

2.2.1 Traffic Volumes

Modeled traffic volumes were extracted from the Future Base Case traffic operations models, as shown in **Figure A.3** and **Figure A.4** (see **Appendix A**) for the typical weekday AM and PM peak hour conditions, respectively. The approximate AM peak hour is 7:00 am to 8:00 pm whereas the PM peak hour is approximately 4:00 pm. to 5:00 pm noting that, given the length of the corridor, the peak hours will differ within the corridor. It is also noted that the traffic volumes represent processed flows from specific road links in the models during the peak hours, therefore minor discrepancies between actual traffic demand and the processed traffic volumes may be evident, especially in locations where congestion occurs and queues form.

Freeway Mainline

Future Base Case mainline segment traffic volumes from the traffic operations models are summarized in **Table 2.5** below. As the data suggest, the study corridor will continue to be heavily traveled during both the typical weekday AM and PM peak periods with traffic volumes exceeding 7000 vph in some segments.

Similar to Existing Conditions, during the typical weekday AM peak hour, the westbound direction is noted with slightly higher traffic flow than the eastbound direction. In contrast, during the typical weekday PM peak hour, the eastbound direction is associated with greater traffic flow than the westbound direction. Also, the PM peak hour volumes are higher than the AM peak hour volumes.

Table 2.5: I-80/94 Typical Weekday AM & PM Peak Hour Mainline Segment Traffic Volumes – Future Base Case

LOCATION	AM		PM	
	WB (vph)	EB (vph)	WB (vph)	EB (vph)
West of I-94/IL 394	7310	6030	6980	7950
East of I-94/IL 394	4730	4280	5050	5830
East of Torrence Ave/US 6/IL 83	5630	5460	6700	7310
East of Calumet Ave/US 41	5890	5550	6940	7460
East of Indianapolis Blvd/SR 152	5950	5680	6840	7540
East of Kennedy Ave	5880	5580	6720	7220
East of Cline Ave/SR 912	6270	5670	6700	7290
East of Burr St	6070	5620	6570	6670
East of Grant St	5900	5700	6600	6680
East of Broadway/SR 53	5650	5450	6170	6740
East of I-65	3840	3550	4310	3780

Freeway Ramps

Future Base Case freeway ramp traffic volumes from the traffic operations models are summarized at all interchange locations along the study corridor, as shown in **Table 2.6**, with high entrance and exit ramp volumes (greater than 800 vph) highlighted in red. Similar to Existing Conditions, high ramp volumes are noted at the two system interchanges. In particular in the eastbound direction, the entrance ramp from I-94 North will carry approximately 2,100 vehicles per hour (vph) during the PM peak hour, and the exit ramp to I-65 South will carry over 2,300 vph in the AM peak hour and approximately 3,300 vph in the PM peak hour. In the westbound direction, the on-ramp from I-65 South will carry approximately 2,100 to 2,200 vph during both the AM and PM peak hours, and the exit ramp to I-94 North will carry over 1,700 vph during the PM peak hour.

Also similar to Existing Conditions, high ramp volumes are also noted at the Calumet Avenue/US 41 and Cline Avenue/SR 912 service interchanges, with almost all ramp volumes being greater than 800 vehicles during both the AM and PM peak hours.

Table 2.6: I-80/94 Typical AM& PM Weekday Peak Hour Ramp Traffic Volumes – Future Base Case

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	1540 1060	1190	1360 160	1750	1040 880	1730	1980 540	2160
Torrence Avenue	770	410	290	590	960	860	660	1290
Calumet Ave/US 41	960	1140	900	800	1260	1440	1710	1520
Indianapolis Blvd	710	760	660	520	940	790	1220	1090
Kennedy Avenue	600	520	350	400	730	540	770	1020
Cline Avenue	1160	1540	1050	960	1300	1240	1530	1410
Burr Street	490	260	330	370	550	360	330	920
Grant Street	450	240	410	340	510	370	640	600
Broadway/SR 53	560	300	290	490	760	300	730	680
I-65 Interchange	540 2200	910	720	2330 290	720 2080	910	790	3280 450

Note: High volume ramps (greater than 800 vph) are shown in red.

2.2.2 Traffic Composition

Compounding the high traffic volumes is the high number of large trucks within the traffic stream. Modeled Future Base Case typical weekday AM and PM peak hour truck percentages are presented in Table 2.7. Similar to the Existing Conditions, the Future Base Case truck percentages are generally lower in the PM peak hour than the AM peak hour, although the actual numbers of trucks may be similar given the typically higher overall traffic volumes during the PM peak periods.

Table 2.7: Modeled Typical Weekday AM & PM Peak Hour Truck Percentages – Future Base Case

LOCATION	AM		PM	
	WB %	EB %	WB %	EB %
West of I-94/IL 394	21	21	17	21
East of I-94/IL 394	25	24	20	24
East of Torrence Avenue	24	23	16	17
East of Calumet Avenue	19	22	15	16
East of Indianapolis Boulevard	19	22	15	16
East of Kennedy Avenue	19	21	16	16
East of Cline Avenue	17	20	15	14
East of Burr Street	18	20	15	14
East of Grant Street	18	20	16	14
East of Broadway	19	21	17	14
East of I-65	24	20	17	15

Section 3 – EXISTING AND FUTURE TRAFFIC OPERATIONS

This section provides a summary of the existing and future traffic operations, with a focus on the AM and PM peak hour conditions on a typical weekday. The accompanying safety analysis involves a detailed review of the crash history along the study corridor to identify the location and magnitude of any potential issues.

In addition to identifying various traffic operations and safety issues under the corridor baseline conditions, the information summarized in this section will form the basis for assessing the performance of several TSMO strategies that are being considered to address any identified issues. This assessment of the TSMO strategies is described in Section 5 and Section 6.

3.1 TRAFFIC ANALYSIS APPROACH

The comprehensive traffic operations (microsimulation) model specifically developed and calibrated for the study corridor, as well as available observed data, was the primary tool applied to analyze both the existing and future corridor conditions in order to assist in identifying any underlying traffic operational issues.

To identify any underlying operational issues, a comprehensive set of performance metrics were developed as a means to thoroughly assess the existing and future operating conditions of the study corridor. The proposed performance metrics applied include overlapping indicators such as corridor travel time, travel speeds, and freeway operations using the Highway Capacity Manual procedures. A description of each performance metric is provided below.

> These specific criteria were also identified to assess the traffic operations associated with the various TSMO strategies being considered, such that a direct comparison can be made between the base line conditions (existing and future) and the operating conditions associated with the TSMO strategies.

3.1.1 Travel Time

Travel time along the length of the study corridor and along several representative routes are proposed as a means of measuring the magnitude of current congestion and possible reductions through the application of one or more TSMO strategies. Travel times will be extracted from the traffic operations models for the following representative routes, the termini of which are shown in **Figure 3.1**:

- Westbound from end to end of the study corridor (I-94 east to I-294 west)
- Eastbound from end to end of the study corridor (I-294 west to I-94 east)
- Westbound from I-94 east to I-94 north
- Eastbound from I-94 north to I-94 east
- Westbound from I-65 south to I-294 west
- Eastbound from I-294 west to I-65 south

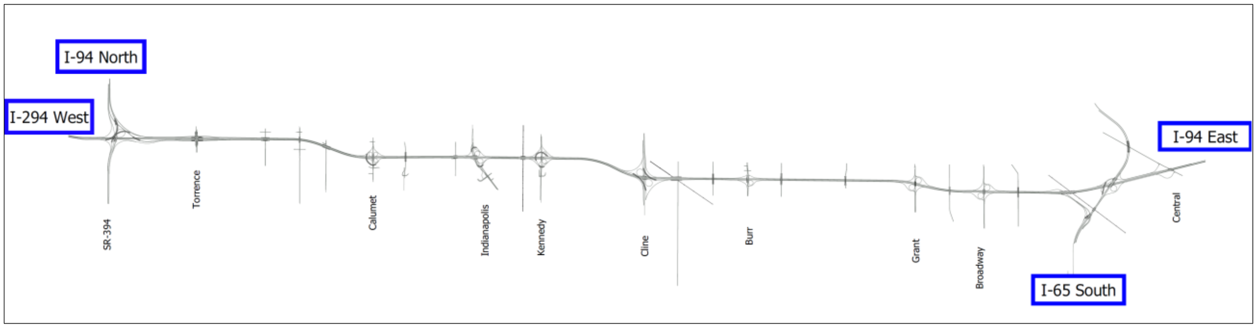


Figure 3.1: Travel Time Route Termini

3.1.2 Freeway Operations - Highway Capacity Manual (HCM) Analysis

The Highway Capacity Software (HCS 7.9) will be applied to assess the basic freeway segments, merge and diverge segments, and the weaving segments along the entire length of the study corridor. Standard HCS output will be reported including level of service (LOS) and density. Traffic volumes for the analysis, including heavy truck percentages, will be extracted from the traffic operations model.

3.1.3 Traffic Speeds

Traffic speeds for the entire corridor will be presented over the analysis period to graphically illustrate locations experiencing lower speeds due to congestion. The traffic speeds reflecting existing conditions are based on observed data obtained from the National Performance Management Research Data Set (NPMRDS), which is a national set of speed / travel time data collected from mobile devices. Data is aggregated to Traffic Message Channel (TMC) codes, referred to as segments. The segments average approximately 0.5 miles in length in urban or suburban areas such as that of the study area. The NPMRDS data acquired is at a 15-minute resolution. The speeds represent average data for the segments, and are presented for the representative days used to develop the traffic operations models. The representative days were determined through a cluster analysis step as part of the model calibration process. The travel speeds are presented for the following representative days:

- Typical Weekday AM peak period – April 28, 2019
- Typical Weekday PM peak period – September 18, 2019

Conversely, the travel speeds representing future conditions are based on data extracted from the traffic operations models. In-road virtual detectors spanning all lanes except the shoulder lane were coded every 250 feet along the I-80/94 corridor. Data was extracted every 10 minutes and represent the average speed across the detector.

3.1.4 Intersection Operations

Intersection capacity analysis using the Synchro software can be conducted to assess the operations of key signalized intersections potentially affecting study corridor operations. Typical outputs would include level of service (LOS) which is based on average vehicle delay, and volume to capacity (v/c) ratio for the overall intersection and key movements. Analysis will be based on peak hour turning movement volumes extracted from the traffic operations models.

The key intersections proposed for this analysis include:

- Broadway Interchange Ramp Terminals (2)
- Grant Street Interchange Ramp Terminals (2)

- Burr Street Interchange Ramp Terminals (2)
- Torrence Avenue Interchange – Single Point Intersection

3.1.5 Queue Formation

The formation of queues and the extent of the queues will be noted based on observations and output from the traffic operations models.

It is noted that this performance metric is primarily focused on the assessment of ramp metering as one possible TSMO strategy, and the potential impacts of queuing along the entrance ramps. For freeway operations, queue formation and the extents are captured through the traffic speed data.

3.2 EXISTING TRAFFIC OPERATIONS

The analysis results for each performance metric is presented in the following sub sections for the typical weekday conditions. A summary of the overall corridor traffic related issues is provided at the end of the section.

3.2.1 Travel Time

Travel time for the key representative routes were extracted from the traffic operations model to represent the average travel time over the peak hour for both the typical weekday AM and PM peak periods. As a means of comparison between the base conditions and the conditions during the typical weekday AM and PM peak periods, free flow travel times for these same representative routes were also obtained through Google Traffic. The Google Traffic travel times were extracted for the 00:00 time period (midnight) and from the range of travel times provided, the lowest value was used. The following table, Table 3.1, summarizes the base travel times, the average travel times, and the travel time delay (difference between the peak period and free flow travel times) for both the AM and PM peak hours.

Table 3.1: Travel Time (Base, Average, Delay)

TRAVEL TIME ROUTE	DISTANCE (MILES)	TRAVEL TIME (MINUTES)				
		Free Flow Travel Time	AM Travel Time	AM Delay	PM Travel Time	PM Delay
I-94 East to I-294 West	18.3	16	19.0	+3.0	19.4	+3.4
I-294 West to I-94 East	18.3	16	18.5	+2.5	23.8	+7.8
I-94 North to I-94 East	18.0	16	18.0	+2.0	24.2	+8.2
I-94 East to I-94 North	18.0	16	18.5	+2.5	18.9	+2.9
I-65 South to I-294 West	17.3	16	17.7	+1.7	18.8	+2.8
I-294 West to I-65 South	17.3	16	17.4	+1.4	23.4	+7.4

Key observations from the above table include:

- Moderate travel time delays during the AM peak hour for all routes. Delays range from approximately one to three minutes. These delay values translate into a percent change ranging from a low of approximately

10% (eastbound from I-294 west to I-65 south) to a high of approximately 20% (westbound over the entire corridor length).

- Significant travel delays are noted during the PM peak hour, with delays ranging from a low of approximately three minutes to a high of over eight minutes. These delays translate into a percent change ranging from a low of approximately 17% (westbound from I-65 south to I 294 west) to a high of over 50% (eastbound from I-94 north to I-94 east). As would be expected, similar levels of delay are experienced for other eastbound routes (eastbound over the entire corridor length, and from I-294 west to I-65 south).

3.2.2 Freeway Operations

Freeway operations were assessed using the latest Highway Capacity Manual procedures and the Highway Capacity Software (HCS 7.9). Traffic volumes and heavy vehicle volumes were extracted from the typical weekday AM and PM traffic operations models for the specific peak hours. Free flow travel speeds were obtained from the National Performance Management Research Data Set (NPMRDS) between the period 12:00 am to 1:00 am on the two representative days. Streetlight Data and traffic operations model outputs were also used to calculate the ramp to ramp volumes between successive interchanges.

The analysis was conducted at the facility level, which involved 37 unique segments as defined by the Highway Capacity Manual. A summary of the analysis results is provided in **Table A.1** to **Table A.4** (see **Appendix A**) that includes the two peak hours and travel directions.

Key observations from the HCS analysis include:

AM Peak Hour (Eastbound – Table A.1)

- The basic freeway segment between the Broadway exit ramp and the Broadway entrance ramp (Segment 30) is operating at a LOS F. This deficient operation may be related to the configuration of the downstream exit to I-65 south (see point below) which requires at least one lane change and two lane changes for many vehicles when traffic demand is high.
- The weave segment between the Broadway entrance ramp and the exit ramp to I-65 south (Segment 31) is operating at a LOS F. As mentioned above, the configuration of the exit ramp to I-65 south requires at least one lane change and two lane changes for many vehicles when traffic demand is high.

AM Peak Hour (Westbound – Table A.2)

- No deficient operations were noted in the westbound direction during the AM peak hour.

PM Peak Hour (Eastbound – Table A.3)

- The freeway segments at the western extent from west of the I-294 interchange to the IL 394 exit ramp (Segments 1 to 2), which are operating at a LOS E or LOS F:
  - The basic freeway segment west of the I-294 interchange (Segment 1) is operating at a LOS E.
  - The weave freeway segment between Oasis and the IL 394 exit ramp (Segment 2) is operating at a LOS F.

  The deficient operation may be related to the high mainline and exit ramp demands in the area, which may lead to turbulence and slowdowns.
- The freeway segments from the Indianapolis Boulevard exit ramp to the Kennedy Avenue entrance ramp (Segments 16 to 18), which are operating at a LOS E or LOS F:

- The basic freeway segment between the Indianapolis Boulevard exit ramp and the Indianapolis Boulevard entrance ramp (Segment 16) is operating at a LOS E.
- The weave freeway segment between the Indianapolis Boulevard entrance ramp and the Kennedy Avenue exit ramp (Segment 17) is operating at a LOS F.
- The basic freeway segment between the Kennedy Avenue exit ramp and the Kennedy Avenue entrance ramp (Segment 18) is operating at a LOS E.

The deficient operation may be related to the high mainline and ramp demands in the area, coupled with the short weaving section between the Indianapolis Boulevard two-lane entrance ramp and the Kennedy Avenue exit ramp (approximately 1,480 feet from the outer lane taper), which may lead to turbulence and slowdowns.

- The freeway segments from the Cline Avenue entrance ramp to the Burr Street entrance ramp (Segments 23 and 24), which are operating at a LOS E or F:
  - The weave freeway segment between the Cline Avenue entrance ramp and the Burr Street exit ramp (Segment 23) is operating at a LOS F.
  - The basic freeway segment between the Burr Street exit ramp and the Burr Street entrance ramp (Segment 24) is operating at a LOS E.

  The deficient operation may be related to the high mainline and ramp demands in the area, coupled with the signage for the Burr Street exit ramp being located at the gore of the Cline Avenue entrance ramp, which may cause unfamiliar drivers to weave immediately which may result in turbulence and slowdowns.

- The freeway segments from the Grant Street exit ramp to the I-65 South exit ramp (Segments 27 through 31), which are operating at LOS F:
  - The diverge freeway segment at the Grant Street exit ramp (Segment 27) is operating at a LOS F.
  - The basic freeway segment between the Grant Street exit ramp and the Grant Street entrance ramp (Segment 28) is operating at a LOS F.
  - The weave freeway segment between the Grant Street entrance ramp and the Broadway exit ramp (Segment 29) is operating at a LOS F.
  - The basic freeway segment between the Broadway exit ramp and the Broadway entrance ramp (Segment 30) is operating at a LOS F.
  - The weave freeway segment between the Broadway entrance ramp and the I-65 South exit ramp (Segment 31) is operating at a LOS F.

  As mentioned previously, the deficient operation may be related to the configuration of the exit to I-65 south, which requires at least one lane change and two lane changes for many vehicles especially when traffic demand is high such as in the PM peak period, thus the issue propagates further upstream compared to the AM peak period.

PM Peak Hour (Westbound – Table A.4)

- The weave freeway segment between the I-65 northbound entrance ramp and the Broadway exit ramp (Segment 7) is operating at a LOS F. The deficient operation may be related to the high traffic demands from the I-65 northbound entrance ramp that merge with the mainline prior to the downstream exit (drop lane – extended auxiliary lane) to Broadway.

3.2.3 Traffic Speeds

Observed traffic speed data from the National Performance Management Research Data Set (NPMRDS) were assessed to further understand traffic conditions along the corridor. Average speed data for the segments that were approximately 0.5 mile in length are presented for the following representative days determined through the cluster analysis step:

- Typical Weekday AM peak period – April 28, 2019
- Typical Weekday PM peak period – September 18, 2019

The traffic speeds have been graphically presented over the length of the corridor (x-axis) and over the course of the day (y-axis). Speeds are depicted by color with green representing near posted speeds and red representing slower speeds.

AM Peak Period

- The traffic speeds for the AM peak period, for the representative day (April 24, 2019), are shown in the speed heat map in **Figure 3.2** for the entire corridor in both the eastbound and westbound directions of travel. As the figures show, there is no congestion observed in either the eastbound direction or westbound direction during the AM peak period (6:00 am to 9:00 am).

  Note: Although the travel speeds for the representative day (AM peak period) do not show any significant reductions as a result of congestion, it is noted that congestion has been regularly observed during the AM peak period in the westbound direction in the vicinity of the I-65 northbound to westbound ramp merge. An example of this regularly occurring congestion at the ramp merge location, as noted by the reduction in travel speeds, can be seen in **Figure 3.2** at around 8:00 am.

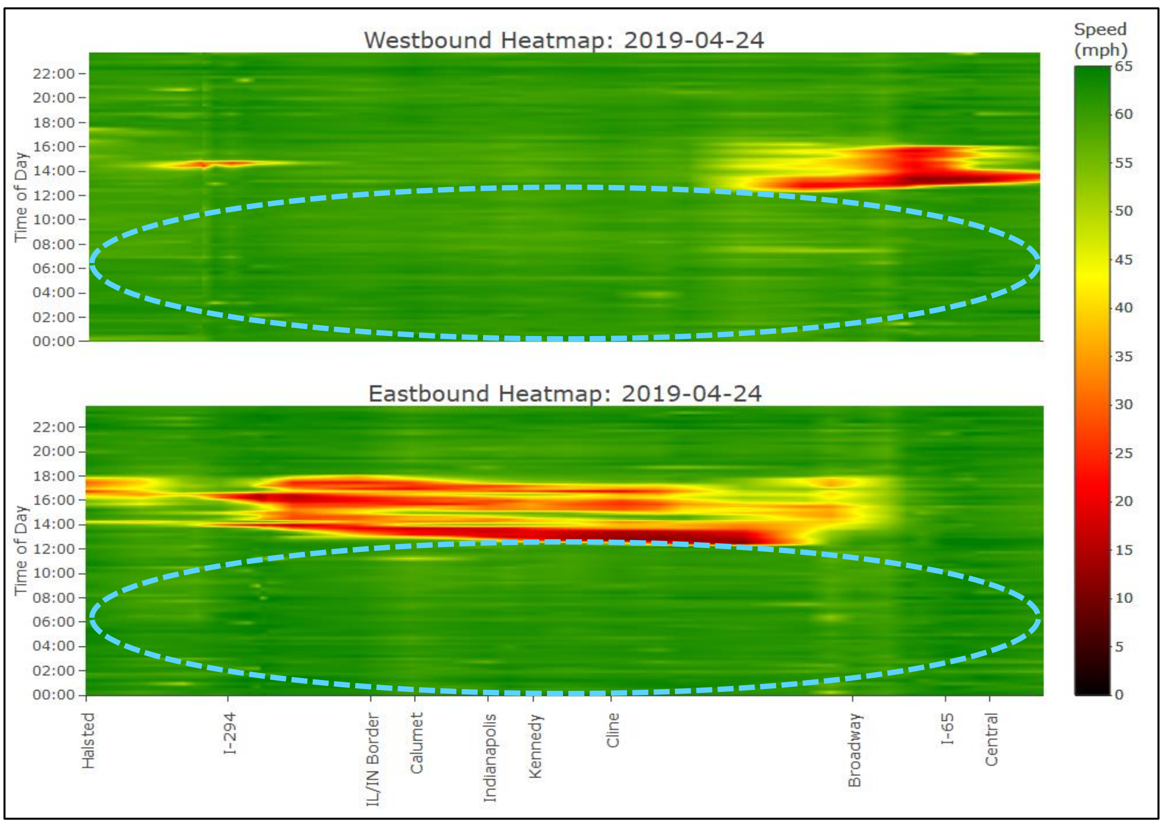


Figure 3.2: Speed Heat Map for Representative Weekday (For AM Peak Period Conditions) – April 24, 2019

PM Peak Period

- The traffic speeds for the PM peak period, for the representative day (September 18, 2019), are shown in the speed heat map in **Figure 3.3** for the entire corridor in both the eastbound and westbound directions of travel. Key observations during the PM peak period (3:00 pm to 6:00 pm) include:
  - Congestion is observed in the eastbound direction for the following segments:
    - Approaching the I-294 interchange.
    - Between the Indianapolis Boulevard interchange and the Kennedy Avenue interchange and possibly related to the entrance ramp at the Kennedy Avenue interchange.
    - Between the Cline Avenue interchange and the Burr Street interchange and possibly related to the entrance ramp at the Burr Street interchange.
    - Between the Broadway interchange and the exit ramp to I-65 south and possibly related to the weave section between the entrance ramp and exit ramp.
  - No congestion is observed in the westbound direction.

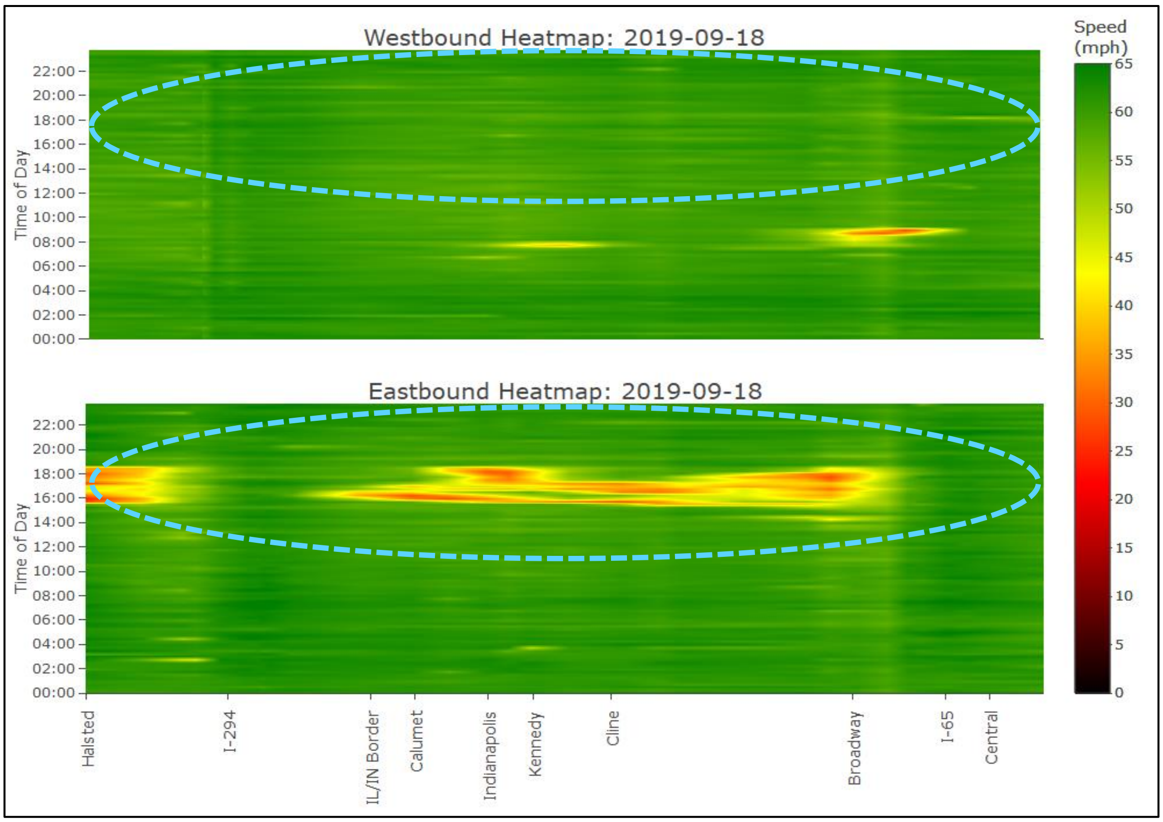


Figure 3.3: Speed Heat Map for Representative Weekday (For PM Peak Period Conditions) - September 18, 2019

3.2.4 Intersection Operations

Intersection capacity analysis, using the Synchro software and peak hour turning movement volumes extracted from the typical weekday AM and PM traffic operations model, was conducted at the seven key intersections that could directly affect traffic operations along the study corridor.

These intersections, all forming part of the interchange, are listed below:

- Torrence Avenue – Single Point Intersection
- Burr Street – north and south ramp terminal intersections
- Grant Street – north and south ramp terminal intersections
- Broadway – north and south ramp terminal intersections

For the purposes of this analysis, LOS which ranges from A to F, a threshold of LOS D was deemed acceptable and therefore values of LOS E or LOS F for any intersection turning movement were noted as being deficient. For the v/c ratio, any intersection turning movement with values exceeding 0.9 were deemed to be deficient and subsequently noted.

The results of the intersection capacity analysis for the seven intersection locations are summarized in **Table A.5** (see **Appendix A**) with respect to the existing performance for each individual movement. For those intersections operating with one or more deficient turning movements, the specific turning movements are identified as follows:

AM Peak Hour Observations

- Torrence Avenue – Single point intersection:
  - Eastbound left-turn movement – LOS E and v/c ratio of 0.91
  - Westbound left-turn movement – LOS E
  - Southbound left-turn movement – LOS E
  - Northbound left-turn movement – LOS E and v/c ratio of 0.99

PM Peak Hour Observations

- Torrence Avenue – Single point intersection:
  - Eastbound left-turn movement – LOS F and v/c ratio of 1.23
  - Westbound left-turn movement – LOS E
  - Southbound left-turn movement – LOS E
  - Northbound left-turn movement – LOS E
- Burr Street Interchange – north ramp terminal:
  - Westbound left-turn movement – LOS F and v/c ratio of 1.01

3.3 FUTURE TRAFFIC OPERATIONS

The analysis results for each performance metric are presented in the following sub sections for the typical weekday conditions for the 2040 planning horizon. For completeness, a comparison to the Existing Conditions (2018/2019) results are provided to demonstrate the relative change to each metric.

A summary of the overall corridor traffic related issues is provided at the end of the section.

3.3.1 Traffic Operations

Future Base Case traffic operations along the study corridor were assessed using the same analysis techniques as applied in the analysis of the existing conditions including output from the Future Base Case traffic operations models, Highway Capacity Manual analysis, and Synchro, in order to identify areas where potential deficiencies or other issues may be occurring. The same performance metrics as applied to assess the existing conditions were also applied to assess the future conditions.

A summary of the analysis for each performance metric is presented in the following sub-sections for the Future (2040) Base Case typical weekday conditions. Comparison to the Existing Conditions (2018/2019) results are provided to demonstrate the relative change to each metric.

3.3.2 Travel Time

Travel time for the key representative routes were extracted from the Future Base Case traffic operations models to represent the average travel time over the peak hour for both the typical weekday AM and PM peak periods. As a means of comparison between the free-flow conditions and the conditions during the typical weekday AM and PM peak periods, free-flow travel times for these same representative routes were also obtained through Google Traffic. The Google Traffic travel times were extracted for the 00:00 time period and from the range of travel times provided, the lowest value was used. The following table, Table 3.2, summarizes the free-flow travel times, the modeled travel times, and the travel time delay (difference between the peak period and free flow travel times) for both the AM and PM peak hours.

Table 3.2: Future Base Case Travel Times

TRAVEL TIME ROUTE	FUTURE BASE CASE TRAVEL TIME (MINUTES)				
	Free Flow Travel Time	Modeled AM Travel Time	Modeled AM Delay	Modeled PM Travel Time	Modeled PM Delay
I-94 East to I-294 West	16	19.5	+3.5	20.7	+4.7
I-294 West to I-94 East	16	19.2	+3.2	33.0	+17.0
I-94 North to I-94 East	16	18.6	+2.6	37.3	+21.3
I-94 East to I-94 North	16	19.0	+3.0	20.1	+4.1
I-65 South to I-294 West	16	19.4	+3.4	21.9	+5.9
I-294 West to I-65 South	16	17.9	+1.9	33.2	+17.2

Key observations from the above table include:

- Moderate travel time delays during the AM peak hour for all routes. Delays range from approximately one minute to three minutes. These delay values translate into a percent change ranging from a low of 5% (westbound over the entire corridor length) to a high of approximately 18% (eastbound over the entire corridor length). These values are in line with the Existing Conditions AM Peak Period scenario, therefore no significant change is noted.
- Significant travel delays are noted during the PM peak hour, with delays ranging from a low of approximately 2.7 minutes to a high of 21.3 minutes. These values are significantly higher than the Existing Conditions PM Peak Period model with the differences ranging from a low of approximately 1.3 minutes to a high of 9.0 minutes.

3.3.3 Freeway Operations

Freeway operations were assessed using the latest Highway Capacity Manual procedures and the Highway Capacity Software (HCS 7.9). Traffic volumes and heavy vehicle volumes were extracted from the Future Base Case traffic operations models for the specific peak hours. The analysis was conducted at the facility level, which involved 37 unique segments as defined by the Highway Capacity Manual. A summary of the Future Base Case analysis results is provided in Table A.6 to Table A.9 (see Appendix A) that included the two peak hours and travel directions.

Key observations from the HCS analysis are presented below, with segments noted to deteriorate into a LOS E or LOS F compared to Existing Conditions (with a LOS D or better) shown in blue.

AM Peak Hour (Eastbound – Table A.6)

- The weave freeway segment between the Grant Street entrance ramp and the Broadway exit ramp (Segment 29) will operate at a LOS F (from a LOS C under Existing Conditions). This deficient operation may also be affected by the configuration of the downstream exit to I-65 south (see point below), which requires at least one lane change and two lane changes for many vehicles when traffic demand is high.
- The basic freeway segment between the Broadway exit ramp and the Broadway entrance ramp (Segment 30) will operate at a LOS F. This deficient operation may also be affected by the configuration of the downstream exit to I-65 south (see point below), which requires at least one lane change and two lane changes for many vehicles when traffic demand is high.
- The weave segment between the Broadway entrance ramp and the exit ramp to I-65 south (Segment 31) will operate at a LOS F. As mentioned above, the configuration of the exit ramp to I-65 south requires at least one lane change and two lane changes for many vehicles when traffic demand is high. The high exiting traffic volume combined with the additional lanes changes to accommodate this traffic along with the entering traffic from Broadway all contribute to the operational issues in this segment.

AM Peak Hour (Westbound – Table A.7)

- The weave freeway segment between the I-65 northbound entrance ramp and the Broadway exit ramp (Segment 7) will operate at a LOS F (from a LOS C under Existing Conditions). The deterioration may be related to the higher demands under future conditions, which may exacerbate the operational issues of high-volume traffic from the I-65 northbound entrance ramp merging with the mainline prior to the downstream exit (drop lane – extended auxiliary lane) to Broadway.

PM Peak Hour (Eastbound – Table A.8)

- The freeway segments west of the IL 394 exit ramp will operate at LOS E (from a LOS D under Existing Conditions). The deterioration may be related to the higher demands under future conditions.
  - The basic freeway segment west of I-94 Interchange - 4 lane section (Segment 1).
  - The weaving section from Oasis to IL-394 exit ramp (Segment 2).
- The freeway segments from the Indianapolis Boulevard exit ramp to the Kennedy Avenue entrance ramp (Segment16 to Segment 18), which will operate at a LOS E or LOS F:
  - The basic freeway segment between the Indianapolis Boulevard exit ramp and the Indianapolis Boulevard entrance ramp (Segment 16) will operate at a LOS E.
  - The weave freeway segment between the Indianapolis Boulevard entrance ramp and the Kennedy Avenue exit ramp (Segment 17) will operate at a LOS F.
  - The basic freeway segment between the Kennedy Avenue exit ramp and the Kennedy Avenue entrance ramp (Segment 18) will operate at a LOS E.
- The freeway segments from the Cline Avenue entrance ramp to the Burr Street entrance ramp (Segment 23 and Segment 24), which will operate at a LOS E or F:
  - The weave freeway segment between the Cline Avenue entrance ramp and the Burr Street exit ramp (Segment 23) will operate at a LOS F.
  - The basic freeway segment between the Burr Street exit ramp and the Burr Street entrance ramp (Segment 24) will operate at a LOS E.
- The freeway segments from the Grant Street exit ramp to the I-65 South exit ramp (Segment 27 through Segment 31), which will operate at LOS F:
  - The basic freeway segment between the Grant Street exit ramp and the Grant Street entrance ramp (Segment 28) will operate at a LOS F.

- The weave freeway segment between the Grant Street entrance ramp and the Broadway exit ramp (Segment 29) will operate at a LOS F.
- The basic freeway segment between the Broadway exit ramp and the Broadway entrance ramp (Segment 30) will operate at a LOS F.
- The weave freeway segment between the Broadway entrance ramp and the I-65 South exit ramp (Segment 31) will operate at a LOS F.

PM Peak Hour (Westbound – Table A.9)

- The weave freeway segment between the I-65 northbound entrance ramp and the Broadway exit ramp (Segment 7) will operate at a LOS F. The deficient operation may be related to the high traffic demands from the I-65 northbound entrance ramp that merge with the mainline prior to the downstream exit (drop lane – extended auxiliary lane) to Broadway.
- The weave freeway segment between the Indianapolis Boulevard entrance ramp and the Calumet Avenue exit ramp (Segment 21) will operate at a LOS E (from a LOS D under Existing Conditions). The deterioration may be related to the higher weaving demands under future conditions.

3.3.4 Traffic Speeds

Travel speeds were assessed using the Future Base Case traffic operations models. Average speed data were collected every 10 minutes from in-road virtual detectors coded every 250 feet along the I-80/94 corridor. Speed contour or heat maps were generated for each direction of travel and each peak period analyzed. The speed heat maps for the AM and PM peak periods are presented in **Figure 3.4** and **Figure 3.5**, respectively. For comparison purposes, the speed heat maps for the existing conditions have also been included.

During the AM peak period, travel speeds remain relatively high, only exhibiting a short period of low-speed congestion in the westbound direction at Burr Street. In contrast, congestion is substantially worse in the PM peak period than the AM peak period. Foremost, the eastbound bottlenecks in the Existing Conditions scenario deteriorate in the Future Base Case scenario with slow speeds between I-294 and Indianapolis Boulevard, between Burr Street and Cline Avenue, and at the approach to the I-65 eastbound exit-ramp. In the westbound direction, a new congested region was observed between Burr Street and Cline Avenue.

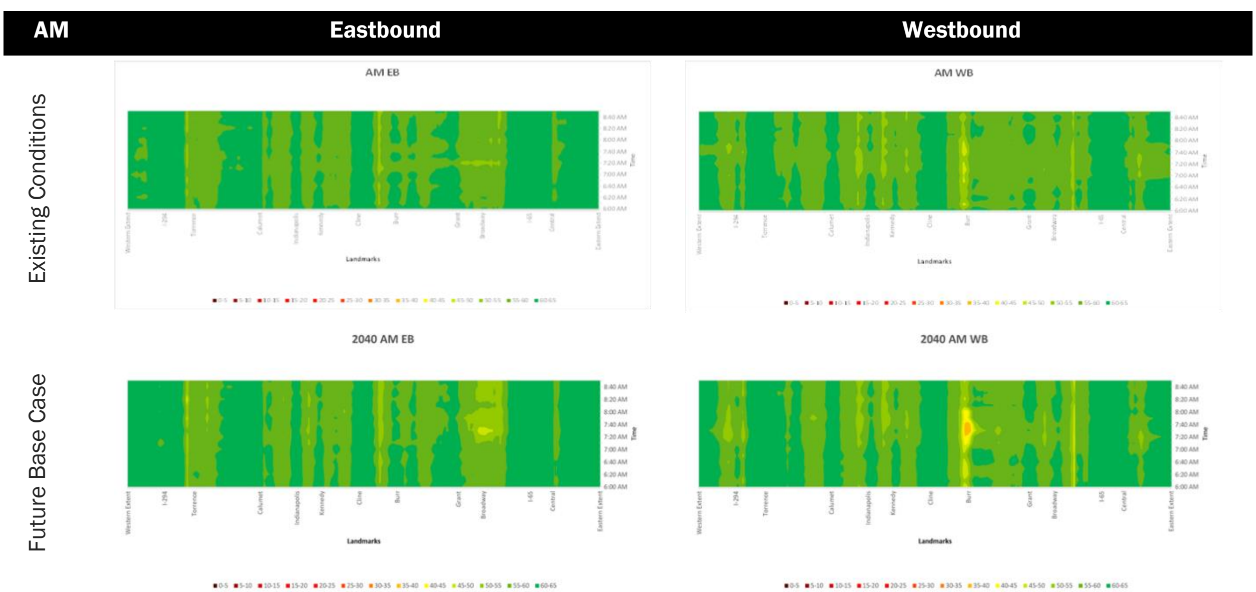


Figure 3.4: Speed Heat Maps - AM Peak Period

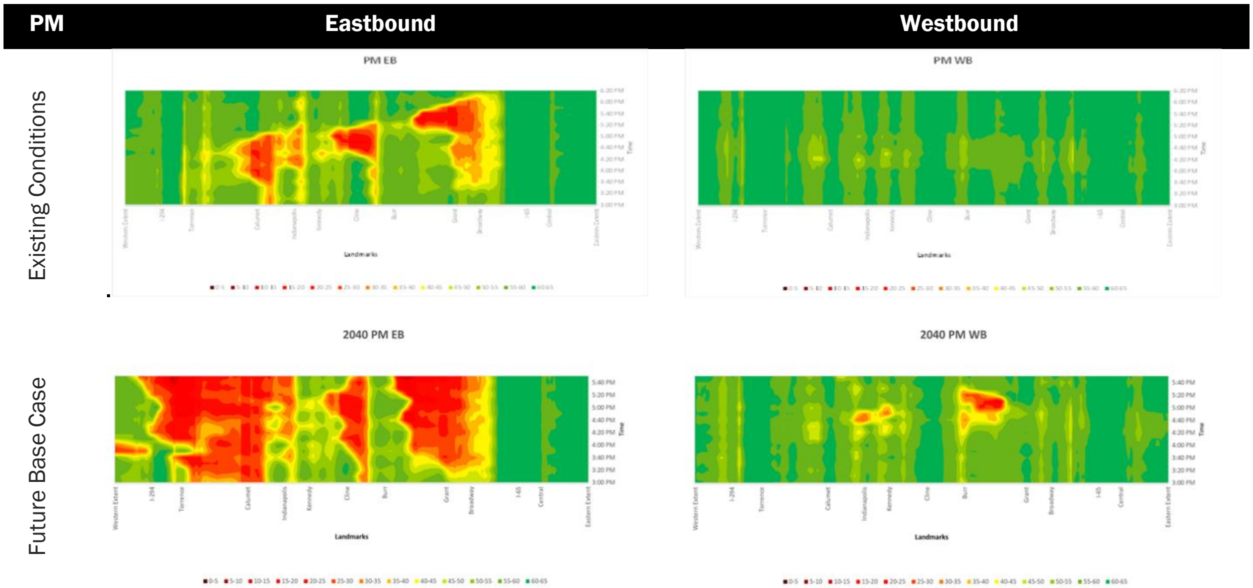


Figure 3.5: Speed Heat Maps – PM Peak Period

3.3.5 Intersection Operations

Intersection capacity analysis using the Synchro software and peak hour turning movement volumes extracted from the Future Base Case traffic operations models, was conducted at the seven key intersections that could directly affect traffic operations along the study corridor. The intersections that form part of the interchanges are listed below:

- Torrence Avenue – Single point intersection
- Burr Street – north and south ramp terminal intersections
- Grant Street – north and south ramp terminal intersections
- Broadway – north and south ramp terminal intersections

For the purposes of the analysis, LOS which ranges from A to F, a threshold of LOS D was deemed acceptable and therefore values of LOS E or LOS F for any intersection turning movement were noted as being deficient. For the v/c ratio, any intersection turning movement with values exceeding 0.9 were deemed to be deficient and subsequently noted.

The results of the intersection capacity analysis for the seven intersection locations are summarized below in **Table A.10** (see **Appendix A**) with respect to the Future Base Case performance for each individual movement. For those intersections operating with one or more turning movements that are deemed deficient, these specific movements are identified in the observations that follows:

AM Peak Hour Observations

- Torrence Avenue – Single point intersection:
  - Eastbound left-turn movement – LOS E
  - Westbound left-turn movement – LOS E
  - Southbound left-turn movement – LOS E

PM Peak Hour Observations

- Torrence Avenue – Single point intersection:
  - Eastbound left-turn movement – LOS E
  - Westbound left-turn movement – LOS F and v/c ratio of 1.16
  - Southbound left-turn movement – LOS E
  - Northbound left-turn movement – LOS E

The above results are similar to the results derived for the existing conditions. However, it was noted that the north ramp terminal at the Burr Street interchange was identified with a deficient movement (westbound left turn at a LOS F) under the existing conditions in the PM peak scenario. With higher demands in the Future Base Case conditions, through trips traversing the entire length of the study corridor appear to cause local trips to use the municipal road network as opposed to the freeway, which may attribute to the lower westbound exit volumes at this location and therefore the improved level of service.

3.4 TRAFFIC SAFETY

To assess the safety performance of the I-80/94 corridor, crash data from the Indiana Department of Transportation (INDOT) and the Illinois Department of Transportation (IDOT) were analyzed for a three-year period from 2017 to 2019, reflecting pre-COVID-19 conditions. The safety review was conducted on a corridor-wide basis to identify high-level trends and characteristics that can be considered in the assessment of the TSMO strategies, and specifically in the estimation of potential benefits.

In addition to the high level corridor wide safety review, detailed analysis was conducted on a segment basis to identify high-crash segments and potential causal factors where possible. High-crash segments were identified using the Road Hazard Analysis Tool (RoadHAT) 3.0 software, which compares observed crash frequencies and estimated crash costs (based on severity) of a segment to expected frequencies and costs based on statewide averages of similar facilities in Indiana. The RoadHAT methodology was applied to the entire study corridor (approximately 16 miles in length), including the portion in Illinois (approximately three miles in length). Although the RoadHAT software employs Indiana state settings, the RoadHAT approach was applied to the Illinois segments in order to provide a comparable assessment across the entire corridor, given the close proximity of the Illinois portion of the corridor to Indiana. IDOT uses a different methodology to identify and prioritize locations for safety improvements. The identified high-crash segments in Illinois were cross-checked with the 2020 IDOT Potential for Safety Improvements (PSI) ratings and Safety Tier Locations provided by IDOT. The detailed high crash segment analysis is attached in Appendix A and can be found in the Existing Traffic Conditions Report which was prepared earlier as part of this study.

3.4.1 Corridor Wide Crash Distribution

The number of crashes for the three-year period (2017-2019) are shown by mile and direction in **Figure 3.6**.

Crash data from INDOT included attributes such as crash severity, crash type, primary factor, vehicle type involved, weather conditions, and road surface conditions, with crash location provided to the nearest one tenth of a mile. Crash data from IDOT, on the other hand, included similar crash attributes except primary factor with crash location provided in a more precise manner using geographic coordinates. Due to the differences in the two crash reporting systems, the high-level corridor wide safety review was conducted separately for the two jurisdictions.

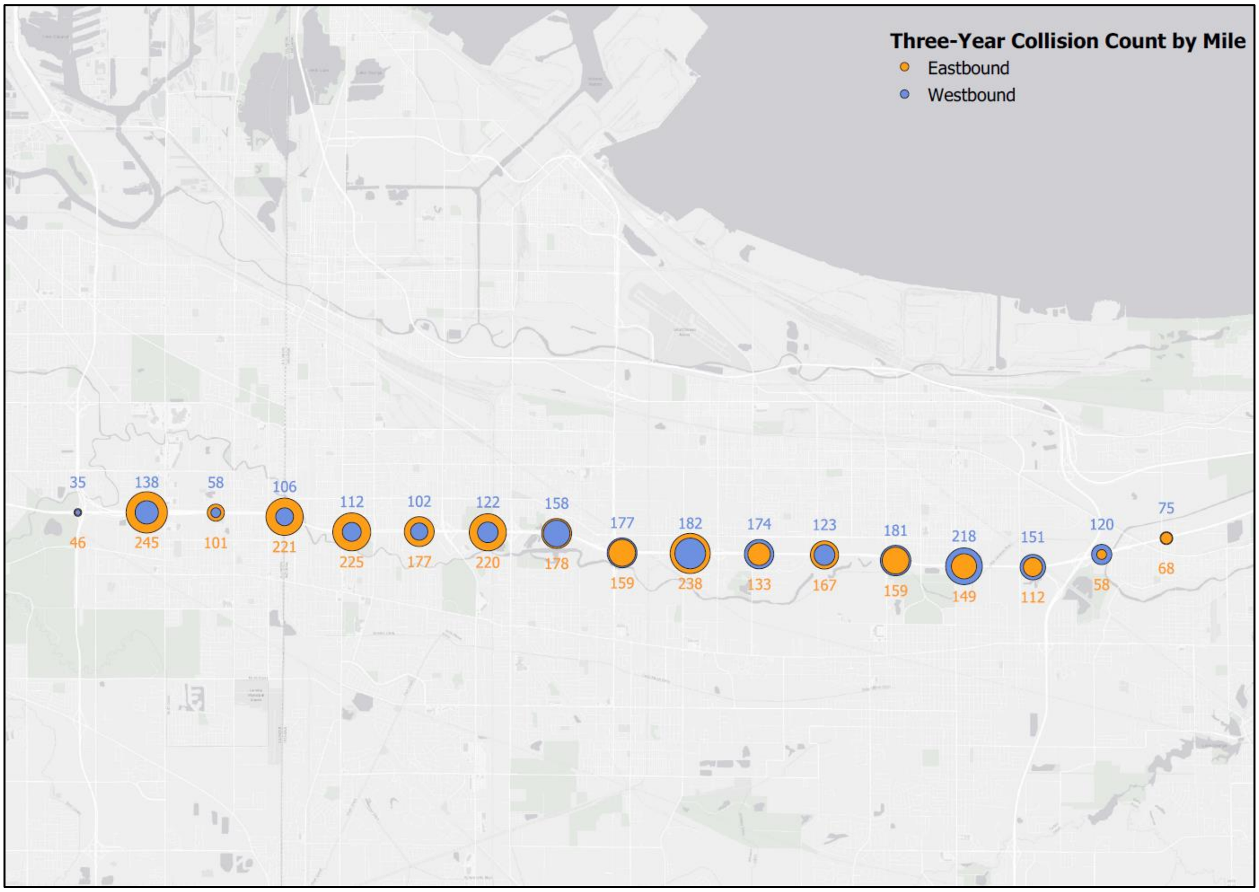


Figure 3.6: Number of Crashes by Mile and Direction (2017-2019)

The available crash data was assessed from various perspectives to provide a better understanding of the crash history with respect to several key indicators such as seasonality, day of week, time of day, severity, vehicle involvement, crash type, and primary factor. The more detailed results of the safety review can be found in the Existing Traffic Conditions Report which was prepared earlier as part of this study.

3.4.2 Temporal Crash Characteristics

Below, a summary of the crashes by month, day of week, and time of day are presented by state.

INDIANA

In total, 4,077 crashes occurred along the corridor between the Illinois/Indiana state line (mile marker 0.0) and just east of the I-65 interchange (mile marker 13.0) over the three-year period from 2017 to 2019. The directional splits were similar, with approximately 52% in the eastbound direction and 48% in the westbound direction. More seasonal variation was observed in the westbound direction, with more crashes noted in the months of July and August, as depicted in **Figure 3.7**. In terms of day of the week, more crashes were noted on Monday and Friday in the eastbound direction, and Friday in the westbound direction, as shown in **Figure 3.8**.

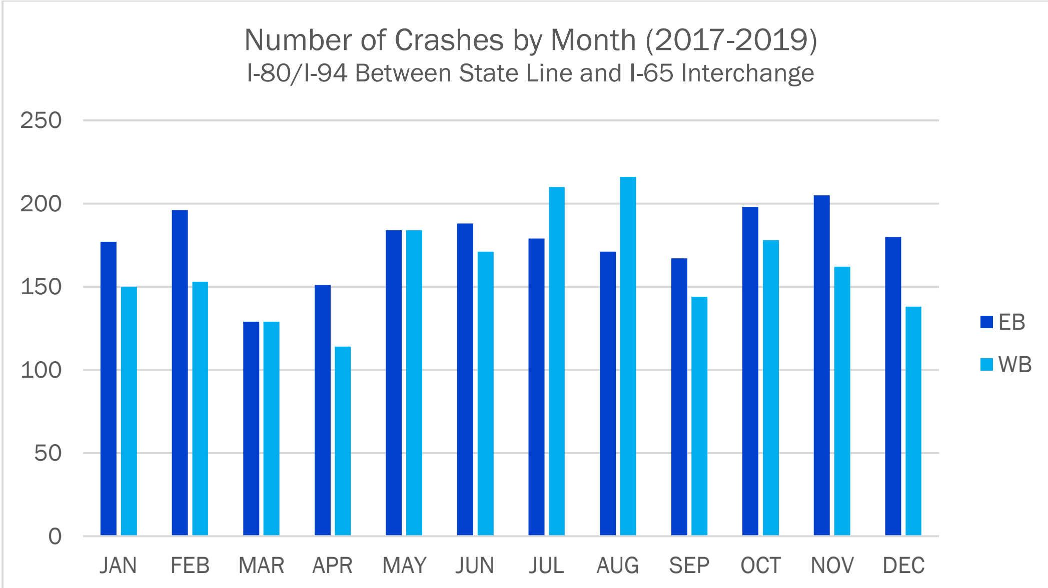


Figure 3.7: Number of Crashes by Month (2017-2019) – Indiana Segment

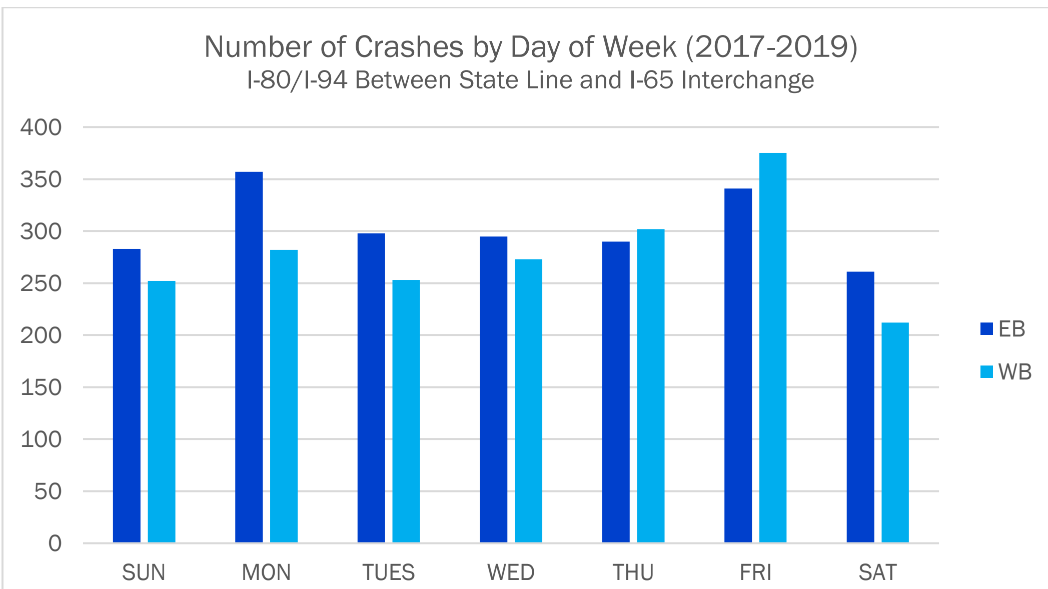


Figure 3.8: Number of Crashes by Day of Week (2017-2019) – Indiana Segment

In terms of time of day patterns, considerably more crashes occurred in the PM peak period (3:00 pm – 6:00 pm) than other periods in the eastbound direction on weekdays, as shown in **Figure 3.9.** In the westbound direction, more crashes occurred in the AM (6:00 am – 9:00 am) and PM (3:00 pm– 6:00 pm) peak periods.

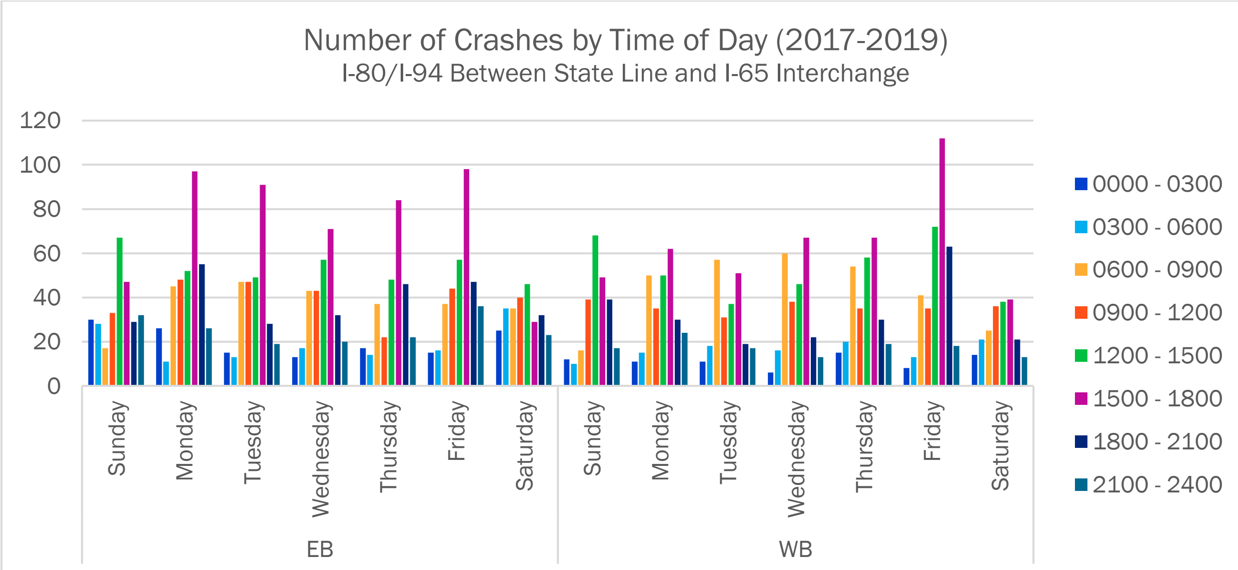


Figure 3.9: Number of Crashes by Time of Day (2017-2019) – Indiana Segment

ILLINOIS

In total, 822 crashes occurred along the Illinois portion of the study corridor between the I-94/80 interchange and the Illinois/Indiana state line (approximately three miles in length) over the three-year period from 2017 to 2019. Notably more crashes occurred in the eastbound direction than in the westbound direction, with a split of approximately 65% compared to 35%, respectively. Different seasonal variations were observed in the two directions, with more crashes in summer (June through September) in the eastbound direction, but more crashes in winter (December through February) in the westbound direction, as shown in Figure 3.10. In terms of day of the week, more crashes were observed on Saturday and Thursday in the eastbound direction, and Saturday in the westbound direction, as shown in Figure 3.11.

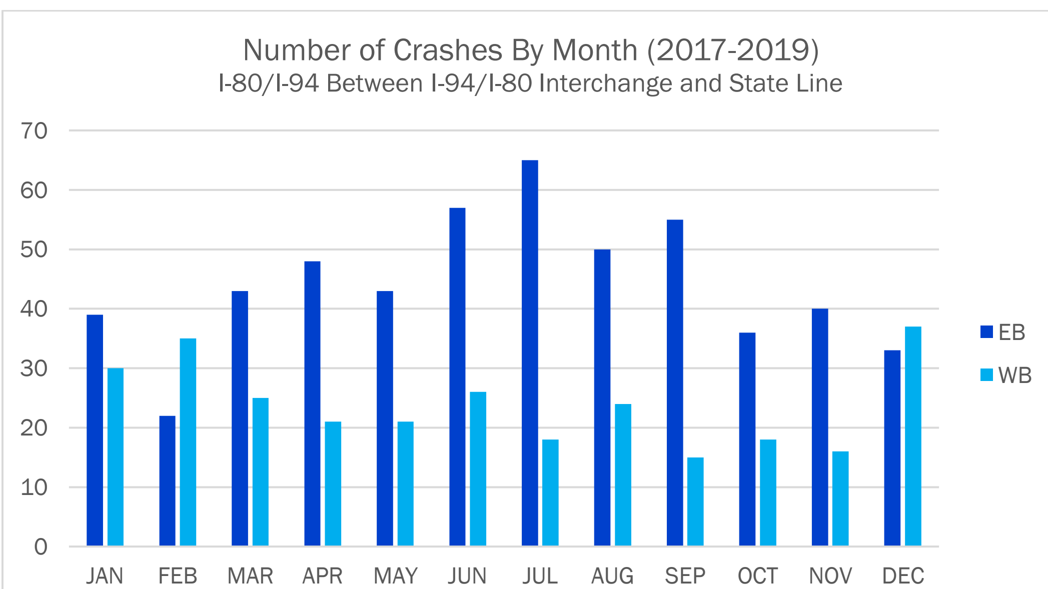


Figure 3.10: Number of Crashes by Month (2017-2019) – Illinois Segment

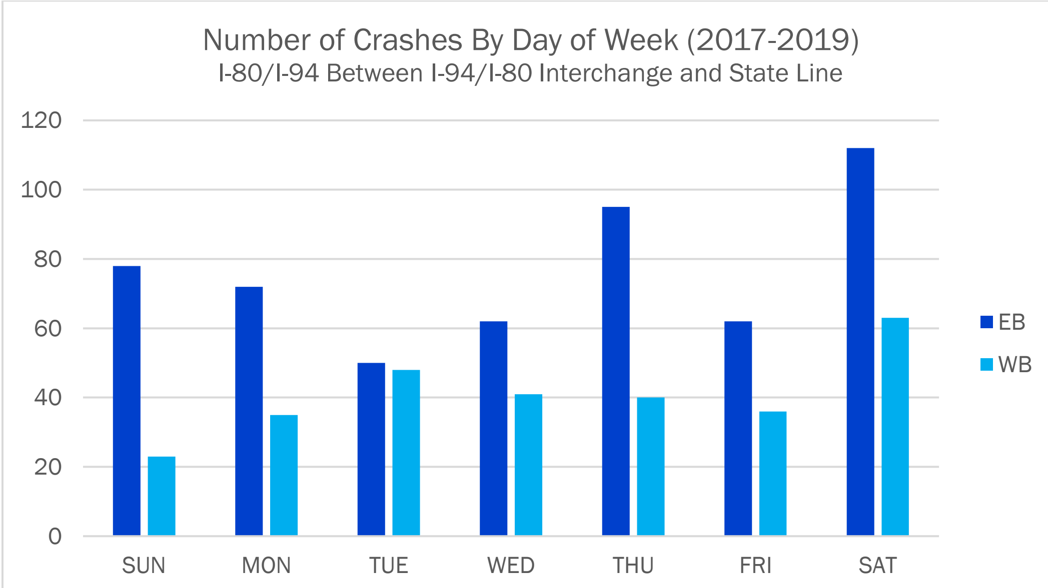


Figure 3.11: Number of Crashes by Day of Week (2017-2019) – Illinois Segment

In terms of time of day patterns, significantly more crashes occurred in the PM peak period (3:00 pm–6:00 pm) than other periods in the eastbound direction on weekdays, as shown in **Figure 3.12**. In the westbound direction, the trend was less pronounced.

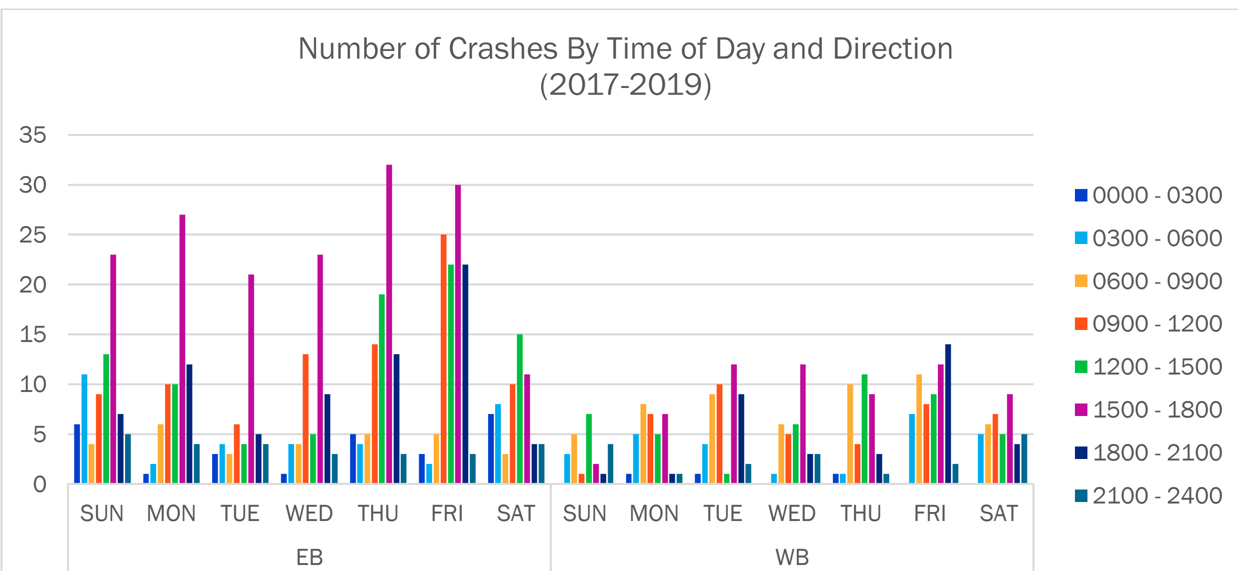


Figure 3.12: Number of Crashes by Time of Day and Direction (2017-2019) – Illinois Segment

3.4.3 Crash Characteristics

A summary of the characteristics of the crashes occurring within the study corridor is presented below in terms of crash severity, vehicle involvement, crash type, and primary factor.

Severity

In terms of crash severity in Indiana, 14% of the total crashes involved an injury, while 86% were property damage only (PDO), as shown in **Figure 3.13**. There were nine fatalities, as well as 322 incapacitating, 80 non-incapacitating, and 176 possible injuries over the three-year period.

In Iliinois,13% of the total crashes involved an injury, while 87% were property damage only (PDO), as shown in **Figure 3.14**. There were three fatalities, 14 suspected serious injuries, 124 suspected minor injuries, and 25 suspected possible injuries over the three-year period.

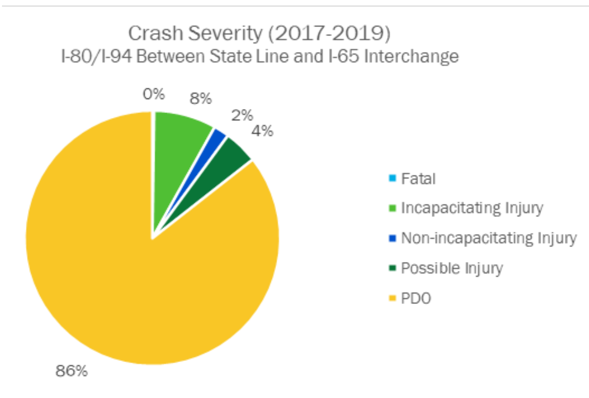


Figure 3.13: Crash Injury (Indiana)

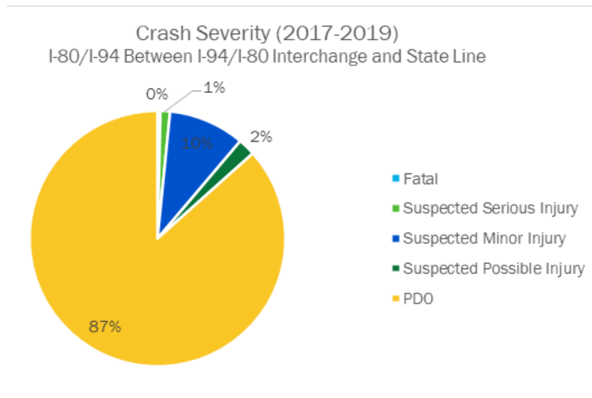


Figure 3.14: Crash Injury (Illinois)

Vehicle Involvement

In terms of vehicle type involved in crashes in Indiana, the proportion of total crashes involving a truck was high. Specifically, 38% of the crashes involved a truck such as a single truck or a tractor trailer, while 62% involved a car but not a truck, such as a passenger car, a pickup, a van, or a sport utility vehicle (SUV), as shown in **Figure 3.15.**

In Illinois, the proportion of total crashes involving a truck was also high. Specifically, 30% of the crashes involved a truck such as a single truck or a tractor trailer, while 70% involved a car but not a truck, such as a passenger car, a pickup, a van, or a sport utility vehicle (SUV), as shown in **Figure 3.16**.

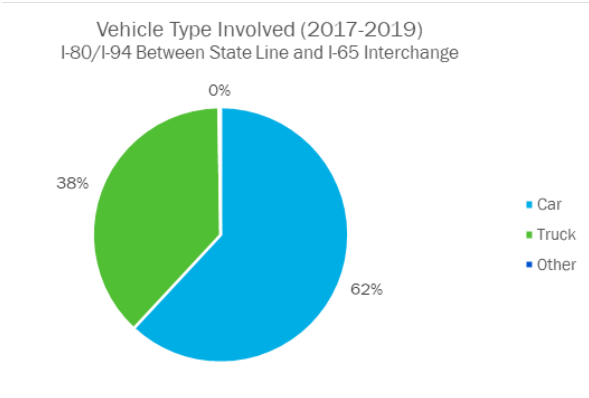


Figure 3.15: Vehicle Involvement (Indiana)

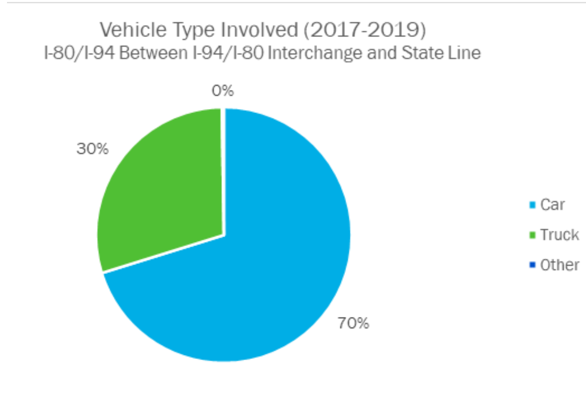


Figure 3.16: Vehicle Involvement (Illinois)

Crash Type

Within Indiana, the predominant crash types noted were rear end (40%), sideswipe (35%), ran off road (12%), and object in road (3%), as shown in **Figure 3:17**. Within Illinois, the predominant crash types noted were rear end (45%), sideswipe (38%), and fixed object (11%), as shown in **Figure 3.18**.

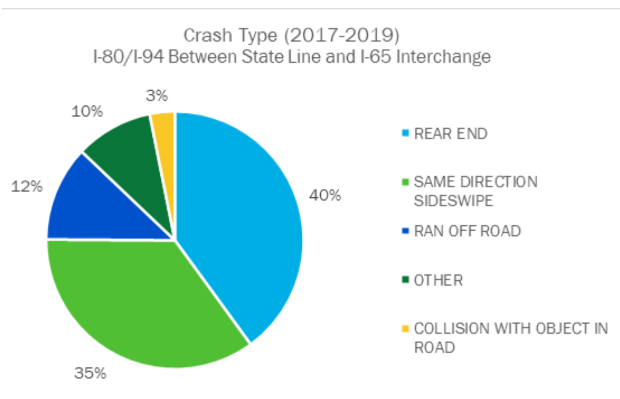


Figure 3.17: Crash Type (Indiana)

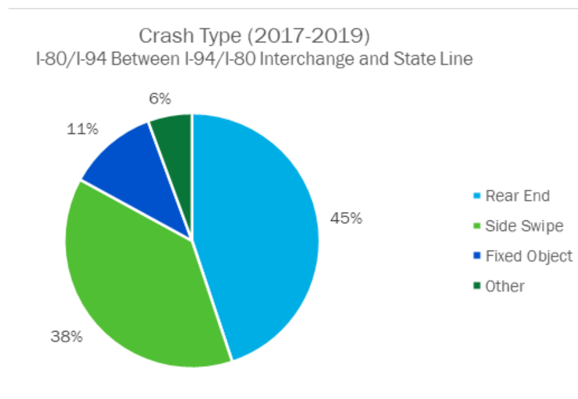


Figure 3.18: Crash Type (Illinois)

3.5 SUMMARY OF CORRIDOR TRAFFIC RELATED ISSUES

Based on the results of the traffic and safety analysis, several findings have been made with respect to potential operating deficiencies or issues along the study corridor. The traffic related issues are summarized in the subsections below.

3.5.1 Traffic Operations – Existing and Future

The key traffic operations related issues are summarized in the following tables with respect to the key performance indicators, including Travel Time, Freeway Operations, Travel Speeds, and Intersection Operations. Though not specifically identified as truck related, the high number of large trucks within the traffic stream combined with the current restriction that trucks are limited to travel on the two rightmost lanes only, affect traffic operations along the corridor as vehicles must weave among the trucks as they enter or exit the freeway.

Table 3.3: Travel Time Performance Issues

LOCATION	DIRECTION	TIME FRAME	DEFICIENCY / ISSUE
Corridor wide	EB	2019 PM 2040 PM	Travel times between I-94 North and I-94 East during the PM peak period are significantly higher as compared to free flow conditions, suggesting congestion in the section between the system interchanges. Travel times are as much as 51% higher than free flow conditions. Conditions deteriorate under the 2040 scenario, with travel times being as much as 133% higher than free flow conditions.
Corridor wide	EB	2019 PM 2040 PM	Travel times between I-294 West and I-94 East during the PM peak period are significantly higher as compared to free flow conditions, suggesting congestion in the section between the system interchanges. Travel times are as much as 49% higher than free flow conditions. Conditions deteriorate under the 2040 scenario with travel times being as much as 106% higher than free flow conditions.
Corridor wide	EB	2019 PM 2040 PM	Travel times between I-294 West and I-65 South during the PM peak period are significantly higher as compared to free flow conditions, suggesting congestion in the section between the system interchanges. Travel times are as much as 46% higher than free flow conditions. Conditions deteriorate under the 2040 scenario with travel times being as much as 108% higher than free flow conditions.

Table 3.4: Freeway Operations Issues

LOCATION	DIRECTION	TIME FRAME	DEFICIENCY / ISSUE
Oasis to IL 394 exit ramp	EB	2040 AM	The weave segment will operate at a LOS E, likely due to higher demands under future conditions.
Grant St entrance ramp to Broadway exit ramp	EB	2040 AM	The weave segment will operate at a LOS F, likely due higher future traffic volumes. The downstream diverge condition at the exit ramp to I-65 south may also affect the freeway operations in this segment.
Broadway exit ramp to Broadway entrance ramp	EB	2019 AM 2040 AM	The basic freeway segment is operating at a LOS F, The downstream diverge condition at the exit ramp to I-65 south may also contribute to the freeway operations in this segment.
Broadway entrance ramp to I-65 exit ramp	EB	2019 AM 2040 AM	The weave segment is operating at a LOS F, likely due to the configuration of the exit ramp to I-65 south which requires a lane change and two lane changes for some vehicles when exiting volumes are high.

LOCATION	DIRECTION	TIME FRAME	DEFICIENCY / ISSUE
Western extent from west of I-294 interchange to IL 394 exit ramp	EB	2019 PM 2040 PM	The segments are operating at a LOS E or F, likely related to the high mainline and ramp demands in the area, which may lead to turbulence and slowdowns. The segments will operate at a LOS F in 2040.
Indianapolis Blvd exit ramp to Kennedy Ave entrance ramp	EB	2019 PM 2040 PM	The segments are operating at a LOS E or F, likely related to the high mainline and ramp demands in the area, coupled with the short weaving section between the Indianapolis Boulevard two-lane entrance ramp and the Kennedy Avenue exit ramp, which may lead to turbulence and slowdowns. The weave segment between the Indianapolis Boulevard entrance ramp and the Kennedy Avenue exit ramp will operate at LOS E in 2040.
Cline Ave entrance ramp to Burr St entrance ramp	EB	2019 PM 2040 PM	The segments are operating at a LOS E or F, likely related to the high mainline and ramp demands in the area, coupled with the signage for the Burr Street exit ramp being located at the gore of the Cline Avenue entrance ramp, which may cause unfamiliar drivers to weave immediately resulting in turbulence and slowdowns. The weave segment between the Cline Avenue entrance ramp and the Burr Street exit ramp will operate at a LOS E in 2040.
Grant St exit ramp to I-65 exit ramp	EB	2019 PM 2040 PM	The segments are operating at a LOS F. The issue at this segment may be affected by the configuration of the exit ramp to I-65 South which requires a lane change and two lane changes for some vehicles when exiting volumes are high, with this issue propagating further upstream compared to the AM peak period. The segments between the Grant Street entrance ramp and the I-65 exit ramp will operate at a LOS F in 2040.
I-65 northbound entrance ramp to Broadway exit ramp	WB	2019 PM 2040 PM 2040 AM	The weave segment is operating at a LOS F, which may be related to the high entering demands that need to merge prior to the downstream exit. The segment will operate at a LOS F in 2040 AM and PM.
Indianapolis Blvd entrance ramp to Calumet Ave exit ramp	WB	2040 PM	The weave segment will operate at a LOS E, which may be related to the higher weaving demands under future conditions.

Table 3.5: Travel Speed Issues

LOCATION	DIRECTION	TIME FRAME	DEFICIENCY / ISSUE
Approach to I-294 I/C	EB	2019 PM 2040 PM	Slower speeds and congestion approaching the I-294 interchange. Conditions deteriorate under the 2040 scenario.
Between the Indianapolis Boulevard I/C and Kennedy Avenue I/C	EB	2019 PM 2040 PM	Slower speeds and congestion between the two interchanges. Possibly related to the entrance ramp at the Kennedy Avenue interchange. Conditions deteriorate under the 2040 scenario, extending back to the I-294 interchange.
Between the Cline Ave I/C and the Burr Street I/C	EB	2019 PM 2040 PM	Slower speeds and congestion between the two interchanges. Possibly related to the entrance ramp at the Burr Street interchange. Conditions deteriorate under the 2040 scenario.
Between the Broadway I/C and the exit ramp to I-65 south	EB	2019 PM 2040 PM	Slower speed and congestion between the two interchanges. Possibly related to the weave section between the entrance ramp and exit ramp and the configuration of the exit ramp to I-65 south. Conditions deteriorate under the 2040 scenario, extending back to as far as the Burr Street interchange.
Approach to the Burr Street I/C	WB	2040 AM 2040 PM	Slower speeds and congestion approaching the Burr Street interchange, which will be more pronounced in the PM peak hour (extending to the Grant Street interchange).

Table 3.6: Intersection Operations

LOCATION	DIRECTION	TIME FRAME	DEFICIENCY / ISSUE
Torrence Avenue – Single point intersection	EB – left turn WB – left turn SB - left turn	2019 AM 2040 AM	LOS E for all four movements Eastbound left-turn movement with a v/c ratio of 0.91 in 2019
	NB - left turn	2019 AM 2040 AM	LOS E in 2019 and LOS F in 2040 v/c ratio of 0.99 in 2019 and 1.07 in 2040
	EB – left turn SB - left turn	2019 PM 2040 PM	Eastbound left-turn movement at a LOS F and v/c ratio of 1.23 in 2019 and 2040 Southbound left-turn movement at LOS E in 2019 and 2040
	WB – left turn	2019 PM 2040 PM	LOS E in 2019 and LOS F in 2040 v/c ratio of 1.16 in 2040
	NB – left turn	2019 PM 2040 PM	LOS E in 2019 and LOS F in 2040 v/c ratio of 0.99 in 2040
	EB – right turn	2040 PM	v/c ratio of 0.93 in 2040
Burr St I/C – north ramp terminal	WB – left turn	2019 PM	Westbound left-turn movement at a LOS F and v/c ratio of 1.01

3.5.2 Traffic Safety Analysis Summary

Key findings from the safety review include the following:

- Crash frequencies higher than state-wide averages were observed in the eastbound direction for almost the full length of the study corridor, and in the westbound direction for many segments.
- Similarly, higher crash severity as indicated by crash costs being higher than state-wide averages was noted in the eastbound direction for almost the full length of the study corridor, and in the westbound direction for many segments. In particular, incapacitating injury crashes accounted for 8% of the crashes in Indiana.
- Significantly more crashes occurred in the eastbound direction during the weekday PM peak period compared to other time periods. In the westbound direction, more crashes occurred during the weekday AM and PM peak periods than other time periods. The time periods correspond with the time periods where recurring congestion occurs.
- A high proportion of crashes was noted to involve trucks, which accounted for 38% of the crashes in Indiana and 30% in Illinois.
- Rear end crashes were noted as the top crash type, which accounted for 40% of the crashes in Indiana and 45% in Illinois. Following too closely was identified as one of the top primary contributing factors, which accounted for 32% of the crashes in Indiana.
- Side swipe crashes were noted as the second highest crash type, which accounted for 35% of the crashes in Indiana and 38% in Illinois. Unsafe lane movement was identified as the top primary contributing factor, which accounted for 36% of the crashes in Indiana.

Section 4 – IMPROVEMENT STRATEGIES

Based on the findings of the *Initial High-Level Assessment of Potential TSMO Strategies* and coordination with the key road authorities in both states, several TSMO strategies have been advanced for more detailed consideration and assessment with respect to the study corridor. Each TSMO strategy being considered further has been tailored for the physical and operating characteristics of the study corridor as a means to potentially mitigate one or more traffic operations and / or safety issues identified in the previous section.

In addition to the key TSMO strategies, several non-TSMO strategies have been developed as a means to address some traffic operations and / or traffic safety issues that may not necessarily be mitigated by a technology application associated with the TSMO strategies under consideration.

Noting the different intended purpose or functionality of the vast array of improvement strategies being considered, the improvement strategies have been grouped and are presented under four categories that represent similar primary purposes, namely, Traffic Operations, Traffic Safety, Event Management, and Non TSMO Corridor Improvements.

4.1 TRAFFIC OPERATIONS TSMO STRATEGIES

This section provides a general description of the scope, operating and / or physical considerations, and the estimated implementation costs for several TSMO strategies that are primarily intended to address the traffic operations related issues identified in the previous section. The traffic operations related TSMO strategies are:

- Dynamic Shoulder Lanes
- Variable Speed Limits
- Ramp Metering

It is also recognized that these TSMO strategies can provide functionality beyond just addressing traffic operations related issues under typical corridor conditions. Where applicable, these Traffic Operations strategies have also been considered as part of the other improvement strategies included under the Traffic Safety and Event Management categories.

4.1.1 Dynamic Shoulder Lanes

The dynamic shoulder lanes strategy enables the use of the shoulder as a travel lane(s), known as Hard Shoulder Running (HSR) or temporary shoulder use, 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 Active Transportation and Demand Management (ATDM) approach continuously monitors conditions and uses real-time and anticipated congestion levels to determine the need for using a shoulder lane. Use of the hard shoulder can be applied to the inside and outside shoulders in both directions along the study corridor. Descriptions for potential use of both the inside and outside dynamic shoulder lanes are provided below:

Inside Shoulder Use

Description

The ability to open the inside shoulder during peak traffic periods could provide significant benefits to traffic flow and travel time reliability. The optimal solution would allow for the use of the shoulder for the entire length of the study corridor during peak traffic hours, however, the exact limits for the eastbound and westbound hard shoulder operations are also dependent upon physical constraints. Based on conceptual design investigations and traffic analysis, the following termini are proposed and graphically depicted in **Figure 4.1:**

- Eastbound Direction:
  - Begin HSR approximately 1500 feet west of the I-94 entrance ramp (physical gore).
  - End HSR within the I-80/94 and I-65 interchange.
- Westbound Direction:
  - begin HSR at the I-65 interchange approximately 1500 feet east of the I-65 entrance ramp.
  - end HSR at approximately 1000 feet east of the Wentworth Avenue overpass structure.

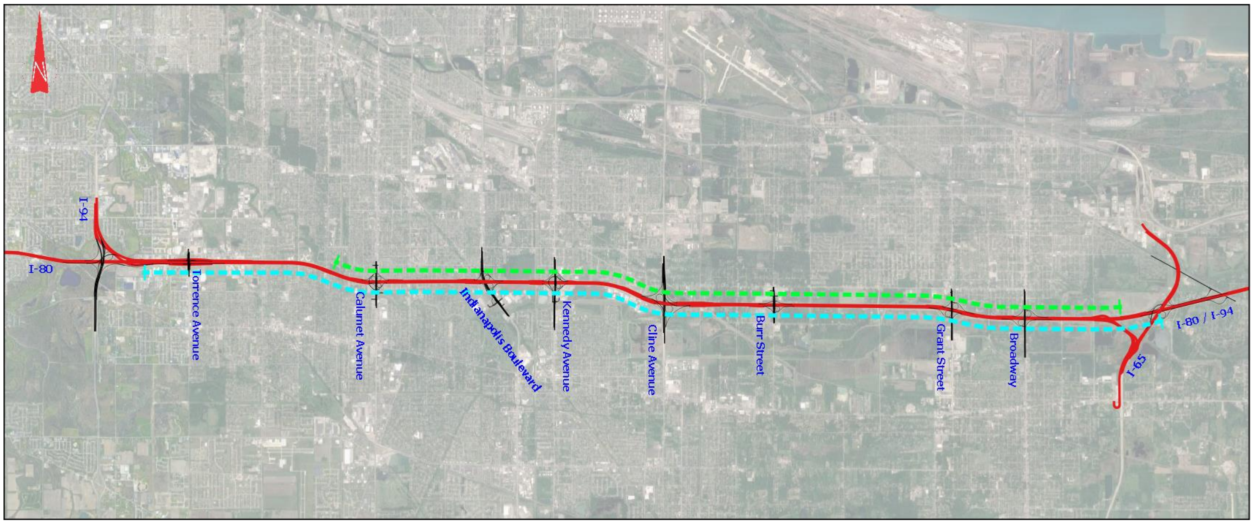


Figure 4.1: Proposed Limits of Inside Shoulder Lane Utilization

To address recurring traffic congestion, the inside shoulders are proposed to be used as dynamic shoulder lanes during the peak periods on the weekdays and potentially on Sundays when the corridor is experiencing higher traffic demand.

Operational Considerations – Inside Shoulder Lanes

The following operational and maintenance issues need to be considered for the proposed use of the inside shoulder lane:

- 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 (see design considerations below)
- Providing appropriate operational staff to manage the use of the lanes and provide additional needed maintenance

Proposed Operating Features: Ingress and egress to the shoulder lane will be permitted at any point along the length of inside shoulder that is open for travel. Lane control signals will be used to indicate whether the shoulder lane is open (downward green arrow) for travel or closed (red X) for travel. Lane control signals will be located at approximately 0.5 mile spacings along the length of the proposed dynamic shoulder lane with tighter spacing at the terminus (approximately the last mile) to provide additional guidance that the shoulder is closed ahead and traffic needs to merge right.

To improve traffic safety, noting the decreased offset between the vehicles using the inside shoulder and the concrete median barrier, it is recommended that the shoulder lane operate at a 45 mph speed limit, which will require the use of electronic variable speed limit signs to differentiate the shoulder posted speed from the 55 mph speed limit for the general purpose lanes. To further improve traffic safety, large vehicles will be restricted from using the inside shoulder lane for travel.

Winter roadway operations changes: Typically snow removal along I-80/94 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. To operate the inside shoulder during the winter months, an additional plow (and drivers) will be needed to clear the inside shoulder along with the rest of the traveled lanes. It is also noted that INDOT recently implemented a Smart Plowing solution that will also add to the efficient snow removal operation. The Smart Plowing solution incorporates real time weather information to optimize salt distribution, plow times and overall plowing operations.

Augmented shoulder cleaning: Currently debris is removed from the shoulders a few times a week, or from the freeway lanes as needed. Typically, the shoulder is raked for larger debris and then swept. Given the amount of debris that collects along the corridor, the inside shoulder will likely need to be raked and swept prior to each opening. Given that the intent is to open the inside shoulder during heavy traffic periods, the inside shoulder may need to be cleaned twice a day, Monday through Friday and Sunday, and as needed on Saturday.

Enhanced law enforcement at opening: With the implementation of hard shoulder running, INDOT should consider enhanced enforcement during the first 90 days of operation to increase motorist compliance with the operating rules. With these types of strategies, it is common to provide enhanced enforcement in clusters, starting with the initial opening.

Physical Infrastructure Considerations – Inside Shoulder Lanes

The inside width of the shoulder on I-80/94 varies throughout the corridor. Both shoulders are 11.8' wide at the western end of the study limits and the shoulders widen out to 14' at the eastern end of the study limits. The typical width of the inside shoulder is also affected by the localized widening of the concrete median barrier to accommodate the foundations for several overhead sign structures and at some bridge pier locations. This localized widening of the median barrier can reduce the inside shoulders by approximately 1.0' in each direction whereas at the Torrence Avenue overpass structure, the median bridge pier widening totals approximately 5.25'.

Noting the shoulder widths available, the following are physical infrastructure considerations that will need to be addressed to utilize the inside shoulder during peak traffic periods or incidents.

- Providing dynamic shoulder riding will reduce the shoulder for allowable spread during rainfall and snow events. There are several alternatives to accommodate the drainage which are identified at the end of the section.
- The existing shoulders were not constructed with load transfer bars. There are several alternatives to manage this situation which are identified at the end of the section.
- Preliminary calculations show three (3) horizontal curves do not meet current standards for super-elevation rates for a design speed of 65 mph (however, horizontal stopping sight distance for 55 mph is provided for the inside shoulder). Also, the high side shoulder breaks in the wrong direction for motorists.
- There are existing ITS features within the median barrier in the Illinois segment. Any possible reconstruction of the median barrier would require proposed work to the current ITS network.

- There are existing ITS features within the pavement. This equipment will need to be considered if reducing lane widths is to be proposed to account for additional width for shoulder riding.
- A majority of the existing bridge abutments and piers, retaining walls and noise walls fall within the zone of intrusion "ZOI." It would be extremely costly and potentially require right of way along both sides of the entire corridor to relocate and reconstruct these infrastructure elements. Recognizing the high costs and potential impacts, this alternative has been considered and eliminated, however, a waiver would still need to be approved.
- Level 1 design exceptions will need to be developed and approved for a 10' shoulder riding lane, reduced shoulders, horizontal stopping distances for design speeds less than 65 mph and possibly vertical stopping distance (which will need to be investigated with survey during final design).
- Existing constraints such as noise walls and R/W, have been considered when identifying locations for new overhead sign structures for lane control.
- Repaving of the Indiana portion of the study corridor is being proposed with construction likely in the 2035 to 2040 timeframe. Consideration should be given to ensure that any overhead sign structures being implemented as part of a TSMO project are designed to be compatible with the repaving project.
- Utilities were investigated using existing plans, 811 website and aerials. Additional investigations will be required during final design, but it is anticipated no utility relocations will be required for any of the proposed work.
- Existing median lighting will most likely be affected if segments of the median barrier need to be removed and reconstructed.

In addition to the above physical considerations within the median, the higher traffic volumes associated with the dynamic shoulder lane may result in increased traffic noise levels within the study corridor. Preliminary investigations have indicated that additional or taller noise barriers may be required in three locations. As such, a cost allowance has been included as part of this TSMO strategy. Detailed analysis of the corridor, using FHWA's Traffic Noise Model, will be conducted during a future phase to confirm any required noise barrier enhancements.

Outside Shoulder Use

Description

The ability to use the outside shoulder during events that reduce the capacity of the general purpose lanes is a potential element as part of several event management related TSMO strategies. Under this type of deployment, segments of the outside shoulder would be opened to provide additional corridor capacity around an event that is blocking one or more general purpose lanes. The extent of the use of the outside shoulder would be flexible and dependent upon the magnitude and location of the lane blockage event. The proposed strategy would allow any segment of the outside shoulder (either direction of travel) within the extent of the study limits and at any time of the day. The proposed extents for potential use of the outside shoulder are defined as follows and are graphically depicted in **Figure 4.2:**

- Eastern Limits: approximately 2000' east of the I-65 northbound to westbound entrance ramp (applies approximately to both directions of travel).
- Western Limits: approximately at the Torrence Avenue overpass (applies to both directions of travel).

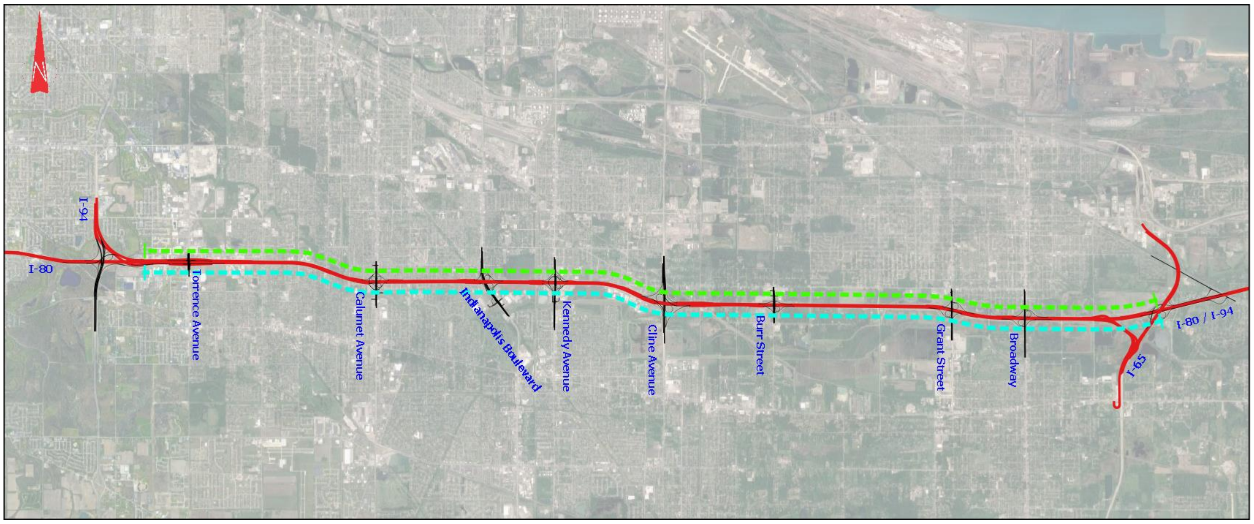


Figure 4.2: Proposed Limits of Outside Shoulder Lane Utilization

Operational Considerations – Outside Shoulder Lanes

Throughout the corridor, in both directions, the lane configuration consists of four (4) general purpose travel lanes with auxiliary lanes. The outside shoulder varies in width from 10' to 14', with the east end of the study corridor possessing the wider shoulder. Much of the study corridor is lined with noise walls directly adjacent to the shoulder, immediately behind the outside barrier. There are several concerns with utilizing the outside shoulder for shoulder riding.

- If traffic is utilizing the outside shoulder in areas with auxiliary lanes, there is the potential for weaving issues at the entrance and exit ramps. This configuration precludes the effective use of the outside shoulder lane for longer distances without some reconfiguration of the various entrance and exit ramps.
- In the case of snow events, as the plows move the snow from the travel lanes to the outside shoulder, it is anticipated that the snow will remain on the shoulder until it melts as the noise walls will act as a barrier to clearing the snow completely off the roadway. This winter maintenance issue may restrict the use of the outside shoulder at certain times during the winter months.
- There is heavy truck traffic in the right lanes throughout the day in both directions of travel. These conditions are not conducive to using the outside shoulder during the peak periods to address recurring congestion as trucks would be discouraged from traveling in the shoulder lane for longer distances at the corridor speed limits. However, there is the potential to use long segments of the right shoulder as a "bypass lane" around incidents during significant accidents or maintenance lane closures.

Proposed Operating Features: Based on the above considerations, the use of long segments of the outside shoulder lane as a "bypass lane" around incidents is proposed. Ingress and egress to the shoulder lane will be permitted at any point along the shoulder that is open for travel. Lane control signals will be used to indicate whether the shoulder lane is open (downward green arrow) for travel or closed (red X) for travel. Lane control signals will be located at approximately 0.5 mile spacings along the length of the proposed dynamic shoulder lane.

To improve traffic safety, noting the decreased offset between the vehicles (including trucks) using the shoulder and the concrete median barrier, it is recommended that the shoulder lane operate at a reduce speed limit in the range of 20 mph to 30 mph. This reduced speed limit also recognizes that the use of the shoulder lane would typically coincide with an incident within the general purpose travel lanes that would dictate that the overall corridor operates at a lower speed. The use of electronic variable speed signs would be used to advise motorists of the change in the posted speed in the vicinity of the incident.

Winter roadway operations changes: No changes in the current operations are proposed as part of utilizing the outside shoulder for travel during an incident management strategy.

Augmented shoulder cleaning: Currently debris is removed from the shoulders a few times a week, or from the freeway lanes as needed. To maintain the flexibility of utilizing the outside shoulders as part of an incident management strategy, it is recommended that enhanced monitoring of the shoulder conditions and additional shoulder cleaning be considered.

Physical Infrastructure Considerations – Outside Shoulder Lanes

The outside shoulder widths vary throughout the study corridor. Shoulder widths are 10' at the western end of the study limits and widen out to 14' at the eastern end of the limits. The shoulder width of 10 feet is not adequate to be considered hard shoulder running as this narrow width would suggest that the shoulder travel lane is only 8' with a 2' barrier offset.

Noting the shoulder widths available, the following are physical infrastructure considerations that will need to be addressed to utilize the outside shoulder as part of an incident management strategy.

- Trucks will use the right 2 "general purpose" lanes, therefore those lanes are required to be 12 feet and unable to be reduced to accommodate a wider outside shoulder.
- Sound walls line a significant portion of the roadway in both directions.
- The existing shoulders were not constructed with load transfer bars. There are three (3) possible pavement design alternatives to address this concern, as described at the end of the section.
- Existing drainage structures are present in the outside shoulder. Type H inlets with and without slotted drain pipe line the roadway. Due to the anticipated infrequent use of the outside shoulder for incident management and maintenance purposes only, and the lower operating speeds when used, it may be cost effective to leave these drainage structures as is.
- Utilities were investigated using existing plans, 811 website and aerials. Additional investigations will be required during final design, but it is anticipated no utility relocations will be required for any of the proposed work.
- Existing ITS infrastructure is located within the outside shoulder for portions of the corridor, generally on the Indiana side only. It is anticipated that the conduit is below the existing subgrade and therefore most likely this conduit will not to be disturbed, however, survey will need to determine the exact locations of the ITS handholes to know if outside shoulder running could affect them.
- It is anticipated that existing lighting will not be affected by outside shoulder running.
- A majority of the existing bridge abutments and piers, retaining walls and noise walls fall within the zone of intrusion "ZOI." It would be extremely costly and potentially require right way along both sides of the entire corridor to relocate and reconstruct these infrastructure elements. Recognizing the high costs and potential impacts, this alternative has been considered and eliminated, however, a waiver would still need to be approved.
- Level 1 design exceptions will need to be developed and approved for a 11' shoulder riding lane, reduced shoulders, horizontal stopping sight distances for design speeds less than 65 mph, and possibly vertical stopping distance (which will need to be investigated with survey during final design).

Estimated Implementation Costs:

Based on the considerations and conceptual design assumptions described above, high level cost estimates have been prepared for the inside dynamic shoulder lane strategy and the outside dynamic shoulder lane strategy. As noted above, there are several alternatives that have been investigated to address some of the design considerations and these are provided below as potential additions to the high-level cost estimates.

For the dynamic shoulder lane strategy, a high-level cost estimate has been prepared which includes several key elements such as field devices, gantries, communications, power, civil infrastructure, design and project management, and contingency. An estimate of the annual maintenance and operating costs for this system is also provided. More detailed costs, including quantities and unit costs, are provided in **Appendix B.**

Table 4.1: Dynamic Shoulder Lanes Implementation Costs

Civil Infrastructure	Cost (rounded)
Superelevation Correction	4,640,000
Pavement Improvements (Alternative 3)	1,940,000
Drainage Improvements (Alternative 5)	1,900,000
Lump Sum (MOT, CE, Clearing, Mobilization/Demobilization)	15,500,000
Noise Barrier Modifications (Provision)	3,670,000
Civil Infrastructure - Subtotal	27,700,000
Systems	**Cost (rounded)**
Cantilever Structures and Foundations	10,900,000
Cantilever equipment/cabling	1,030,000
Lane control signs	1,920,000
CCTV cameras	512,000
Cabinets, handholes, power service, communications	3,960,000
Central ATM software	350,000
Communications redundancy and protection of existing equipment	500,000
Dynamic message sign on new dedicated gantry	230,000
DMS gantry structure and foundation	440,000
Integration and testing (2% of construction cost)	397,000
Systems Subtotal	20,300,000
Design (10%)	4,790,000
Project Management (5%)	2,400,000
Subtotal	**55,100,000**
Contingency (30%)	16,600,000
Total	**71,600,000**
Yearly operations and maintenance	615,000

Possible Civil Infrastructure Design Alternatives

If the dynamic shoulder lane strategy is advanced to the next design level, it is noted that the inside shoulder is generally wide enough to be recommended but the outside shoulder riding is only recommended where the existing width is 12 feet or greater. The proposed typical section, shown in **Figure 4.3,** would provide a 10' riding lane within the existing inside shoulder with the remainder to be barrier offset. The outside shoulder riding lane width is recommended to be 11' with the remainder being barrier offset. Both travel lane widths and shoulder widths will need level 1 design exceptions as they are substandard for interstate highways.

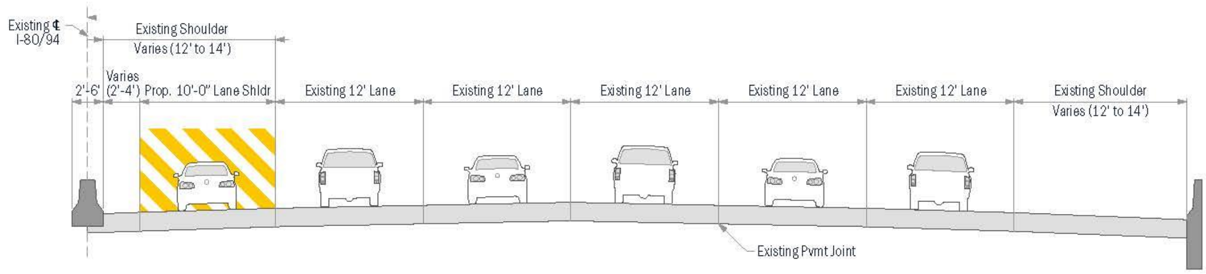


Figure 4.3: Proposed Typical Section of Inside Dynamic Shoulder Riding for Eastbound Direction (Westbound would mirror the typical sections)

In order for the corridor to be able to handle dynamic shoulder riding, the following items are mitigation measures that would assist traffic to be utilized on the shoulders.

- **Superelevation Correction (Inside shoulder)** $4.64 Million

  Four of the existing horizonal curves within the study limits do not meet current superelevation standards and transitions for design speeds for 65 mph. The high side shoulder breaks the cross slope in the opposite direction of all the curves. It is anticipated that design exceptions will be applied for and granted for the general purpose lanes but if the inside shoulder is on the high side of the typical section, it will be reconstructed to be sloped in the same direction as the adjacent lanes. Reconstruction of the shoulders will result in reconstruction of the median barrier to a bifurcated median barrier.

  Superelevation Correction (Outside shoulder)

  There are no superelevation correction improvements recommended for the outside shoulder as the dynamic shoulder is only being recommended for incident management and maintenance purposes. The uses will be infrequent with vehicles operating at low speeds.

- **Pavement Improvements (Cost inside shoulder and outside shoulder are the same)**

  Three alternatives have been developed to address the physical infrastructure considerations as they relate to pavement improvements.

  Pavement Alternative 1 $12.1 Million/($24.2 Million for both)

  Alternative 1 provides retrofitted load transfer bars in the shoulder and assumes joint repair to 10% of the longitudinal joints.

  Pavement Alternative 2 $7.8 Million/($15.6 Million for both)

  Alternative 2 provides retrofitted load transfer bars within the wheel path of the inside and outside shoulders and assumes joint repair to 10% of the longitudinal joints.

  Pavement Alternative 3 $0.9 Million/($1.8 Million for both)

  Alternative 3 provides joint repairs for the inside and outside shoulders. The cost associated equates to 10% of the project length for the inside and outside shoulder, for the limits of dynamic shoulder lane. This alternative does not recommend retrofitted load transfer bars for the inside shoulder as trucks will be restricted. The outside shoulder is anticipated to only be used infrequently for incident management and maintenance purposes. The uses will be infrequent and at lower speeds.

- **Drainage Improvements (inside shoulder)**

A total of five alternatives were developed to address the physical infrastructure considerations related to drainage that could potentially impact the operation of an inside shoulder lane.

Drainage Alternative 1: Do nothing — No Additional Funds

Alternative 1 is to leave the existing drainage as is, meaning no improvements will be made. For maintenance of traffic purposes, traffic has been moved to the inside shoulder full time during the course of previous construction projects in the corridor. These schemes utilized the shoulder during rain events without improvements and vehicle travel over the slotted drains.

Drainage Alternative 2: — $29.6 Million

Alternative 2 involves providing drainage improvements to meet current INDOT standards for intensity (amount of rainfall over a time period, based NOAA figures) and the INDOT allowable spread (accumulation of flow next to the median barrier) up to the edge of the travel lane. This alternative also includes removing existing slotted drains, ensuring castings meeting existing grades, and clean out of the existing structures.

Drainage Alternative 3 — $15.6 Million

Alternative 3 involves providing drainage improvements to meet current FHWA standards of 4 in/hr intensity and the INDOT allowable spread up to the edge of the travel lane. This alternative also includes removing existing slotted drains, ensuring castings meet existing grades, and clean out of the existing structures.

Drainage Alternative 4 — $11.1 Million

Alternative 4 involves providing drainage improvements to meet current FHWA standards of 4 in/hr intensity and the INDOT allowable spread for freeway ramps (3.0 feet onto the ramp). This alternative also includes removing existing slotted drains, ensuring castings meet existing grades, and clean out of the existing structures.

Drainage Alternative 5 — $1.8 Million

Alternative 5 involves leaving the existing drainage system as is and not providing additional structures. However, this alternative would include removing the existing slotted drains, ensuring castings meet existing grades, and clean out of the existing structures.

Drainage Improvements (outside shoulder)

There are no drainage improvements recommended for the outside shoulder as the dynamic shoulder is only being recommended for incident management and maintenance purposes. The uses will be infrequent and at lower speeds.

Estimated Additional Maintenance and Operations Costs:

In addition to the capital costs associated with these strategies, there may also be some impacts related to ongoing maintenance and operations activities. These items have been identified below along with a high level annual cost estimate:

- **Winter roadway operations changes:** It is not clear at this time if an additional plow truck would be required, or just an additional maintenance person. It is understood that INDOT already has an order for 72 new trucks next year. This additional person would be able to support plowing in the winter and debris removal throughout the year.
- **Augmented shoulder cleaning (road raking and sweeping for debris):** As noted above, one additional maintenance person could support the additional plowing needs and support the additional debris removal required for the HSR.

  An additional maintenance person could cost between $40,000 and $80,000 per year. For the purposes of this study and specifically the alternative assessment, an annual cost of $70,000 was applied in the development of the overall costs of these strategies.

4.1.2 Variable Speed Limits

Description

This strategy adjusts speed limits based on real-time traffic, 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. In an ATDM approach, real-time and anticipated traffic conditions are used to adjust the speed limits dynamically to meet typical agency goals and 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 in or before areas of congestion, incidents, or special events to maintain smooth traffic flow and to reduce the risk of collisions due to speed differentials. These variable speed limit systems are usually used in conjunction with other ATM strategies such as queue warning and hard shoulder running.

For the I-80/94 study corridor, the variable speed limit strategy proposes that the system be located throughout the corridor and in both directions of travel. The variable speed limit messaging would start approximately three (3) miles prior to the study limits at the I-294 interchange in the west and at the I-65 interchange in the east. These start points will allow speeds to be brought down prior to the active study area between the two terminus points. The proposed spacing for the variable speed limit signs is approximately 0.5 miles as shown in **Figure 4.4** (Indiana Segment) and **Figure 4.5** (Illinois Segment). Most of the signs are mounted on overhead gantries (in conjunction with other field devices such as lane control signals), such as the ones shown in **Figure 4.6**. Additional standalone VSL signs are located in advance of the corridor at each end.

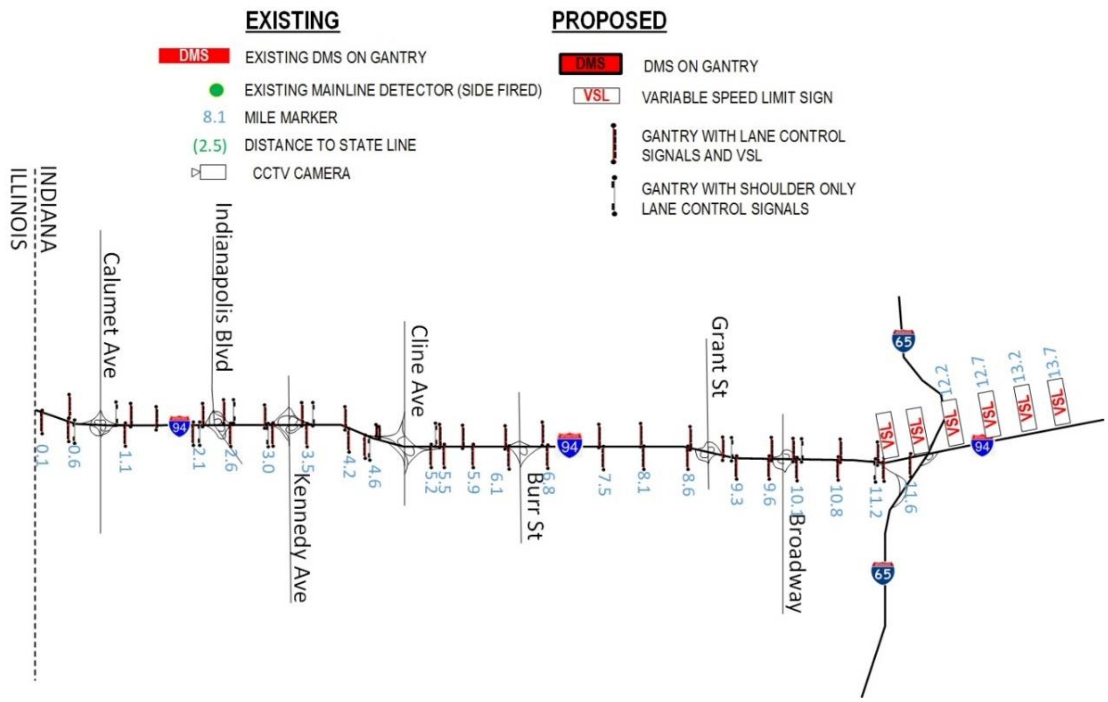


Figure 4.4: Preliminary Variable Speed Limit Sign Locations in Indiana

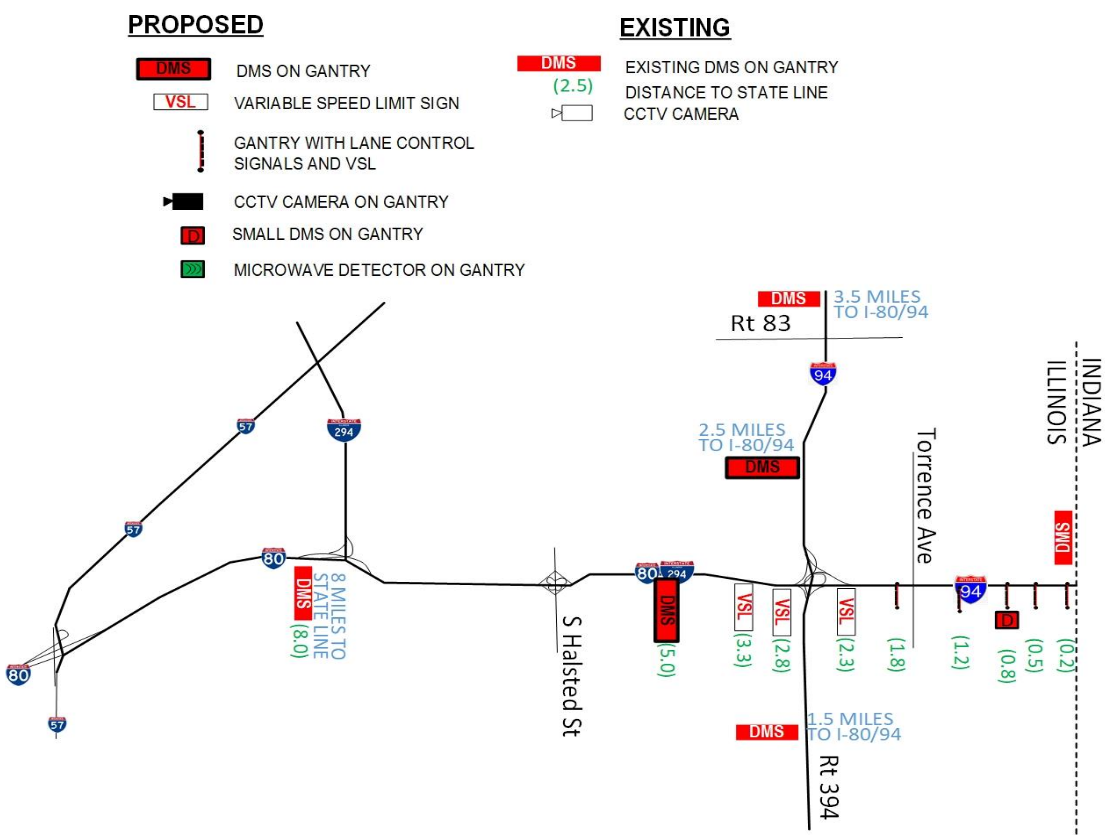


Figure 4.5: Preliminary Variable Speed Limit Sign Locations in Illinois

Figure 4.6: Example Overhead Gantries with Variable Speed Limit and Dynamic Message Signs

An integrated system with variable speed limits, hard shoulder running, lane control, and queue warning over the entire length of the study corridor would present an opportunity for all the associated field devices to be located on the same set of sign gantries which would reduce implementation costs significantly. However, the variable speed limit sign located in advance of the active study corridor would be located on standalone sign structures in any integrated system scenario.

Operational Considerations

Several operational considerations or features associated with the variable speed limit strategy are presented below:

- A key part of the benefits in providing variable speed limits is the ability to gradually step down the speed limit from the normal posted speed limit to the desired speed. Between each variable speed sign, speed reductions or step downs would be in either 5 mph or 10 mph increments.

- Measuring speeds in the immediate vicinity of each variable speed sign is a critical part of the effective operation of the variable speed limit system. Although there are existing detectors throughout the corridor, they are nearing the end of their service life, and it is preferred that new side-fired radar vehicle detectors would be installed to measure speed in each lane at each sign / gantry location.
- Speed limits for variable speed limit systems used for to manage congestion are generally updated every 30 seconds to 15 minutes. An interval of one to five minutes was found to be the most common practice.
- Ideally, the variable message signs will be located over the lanes, if gantry mounted, or adjacent to each shoulder if no gantries are included. The exact message display details will be addressed as part of a future design phase; however, it is anticipated that the DMS display would provide flexibility in the ability to display both variable speed limit graphics and lane control graphics simultaneously.

A key consideration in the implementation of a variable speed limit strategy in the study corridor is the current legislation regarding use of variable speed limits. In Indiana, the current legislation allows for regulatory variable speed limits whereas in Illinois, the legislation does not permit regulatory use of variable speed limits. Noting the difference in the legislation in each state, it is proposed that the VSL strategy includes advisory speed limits in Illinois and regulatory speed limits in Indiana. Further investigation during future phases should be considered to confirm the use advisory and/or regulatory variable speed signs.

As indicated under the dynamic shoulder lane strategy, variable speed limit signs are proposed in order to reduce the speed limit in the shoulder lane to improve traffic safety noting the limited offset distance between the vehicles and the median barrier. A reduced speed limit of 45 mph in the shoulder lane is proposed. Coordination between a full corridor variable speed limit strategy and the operation of the dynamic shoulder lane will need to be addressed to minimize the effects of differential speeds between lanes if both TSMO strategies are advanced.

Physical Infrastructure Considerations

The following are physical infrastructure considerations that will need to be addressed to implement variable speed limits within the study corridor:

- With four or five lanes throughout the study corridor and heavy truck traffic, special consideration will need to be given to the placing of the variable speed limit signs to ensure adequate viewing opportunities.
  - Side mounted variable speed limits signs are not preferred, however, if full gantries are not provided, mounting the speed limit signs on each shoulder (inside and outside) would be satisfactory.
  - Foundations for side mounted sign structures would require modifications to the median barrier. Foundations for full width gantries would also require modifications to the median barrier. The modifications to the barrier to accommodate placement of new gantry supports in the median will require expansion of the median barrier by approximately 1.0 feet in each direction which will reduce the available cross section for other TSMO strategies such as dynamic shoulder lanes. In addition, the outside shoulder is frequently adjacent to a sound wall. Reconstruction of the sound wall in that area may be required to allow for the placement of the outside gantry support.
- Full width gantries would be used for a lane control system; therefore, these gantries would be available to mount the variable speed limit signs over each lane if both strategies are selected.

Estimated Implementation Costs

For this strategy, as tailored for the study corridor, a high-level cost estimate has been prepared which includes several key elements such as the field devices, cabinets, power and communications, design and project management, and contingency. An estimate of the annual maintenance and operating costs for this system is also provided More detailed costs, including quantities and unit costs, are provided in **Appendix B**.

Table 4.2: Variable Speed Limit System Implementation Costs

Civil Infrastructure	**Cost (rounded)**
Lump Sum (MOT, CE, Clearing, Mobilization/Demobilization)	4,250,000
Pavement Patching & Removal	735,000
Civil Infrastructure - Subtotal	4,990,000
Systems	**Cost (rounded)**
Inside/outside shoulder VSL's	3,830,000
Cabinets, handholes, power service, communications	3,520,000
Microwave radar detector	342,000
Communications redundancy and protection of existing equipment	500,000
Standalone VSL's	320,000
Integration and testing (2% of construction cost)	171,000
Systems Subtotal	8,680,000
Design (10%)	1,370,000
Project Management (5%)	683,000
Subtotal	**15,800,000**
Contingency (30%)	4,720,000
Total	**20,500,000**
Yearly operations and maintenance	174,000

4.1.3 Ramp Metering

Description

Ramp meters are traffic signals installed on freeway entrance-ramps to control the frequency at which vehicles enter the flow of traffic on the freeway. Vehicles traveling from an adjacent arterial roadway would stop at the ramp meter stop line / traffic signal and then be individually released onto the freeway mainline, often at a rate that is dependent on the current mainline traffic volume and speed.

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

Adaptive Ramp Metering is a specific ramp metering application that dynamically controls the rate vehicles enter a freeway facility. 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 traffic volumes on the freeway facility are used to control the metering rate of vehicles entering the freeway facility. Based on the freeway operations, the ramp meter rates will be adjusted dynamically.

For the I-80/94 corridor, ramp meters are proposed at the following interchange locations as shown in **Table 4.3**. For each ramp meter location, the estimated traffic volumes in 2019, the approximate queue storage available, and the number of lanes on the ramp are also shown for reference. Graphics showing the proposed location for each ramp meter signal at each interchange location are provided in **Appendix C.**

Table 4.3: Proposed Ramp Meter Locations

<table>
<tr><th>INTERCHANGE</th><th>RAMP</th><th>EXISTING LANES</th><th>PEAK VOLUME (VPH)</th><th>QUEUE STORAGE (FEET)</th></tr>
<tr><td rowspan="3">Calumet Avenue</td><td>NB &SB to EB</td><td>2</td><td>1480</td><td>>700 | >2200</td></tr>
<tr><td>NB to WB</td><td>1</td><td rowspan="2">1130</td><td>>600</td></tr>
<tr><td>SB to WB</td><td>1</td><td>>700</td></tr>
<tr><td rowspan="3">Indianapolis Boulevard</td><td>NB & SB to EB</td><td>2</td><td>1080</td><td>>1400 | >1400</td></tr>
<tr><td>NB to WB</td><td>1</td><td rowspan="2">840</td><td>>825</td></tr>
<tr><td>SB to WB</td><td>1</td><td>>850</td></tr>
<tr><td rowspan="3">Kennedy Avenue</td><td>NB & SB to EB</td><td>2</td><td>820</td><td>>850 | >1500</td></tr>
<tr><td>NB to WB</td><td>1</td><td rowspan="2">550</td><td>>700</td></tr>
<tr><td>SB to WB</td><td>1</td><td>>850</td></tr>
<tr><td rowspan="4">Cline Avenue</td><td>NB to EB</td><td>1</td><td rowspan="2">1490</td><td>>2000</td></tr>
<tr><td>SB to EB</td><td>1</td><td>>2600</td></tr>
<tr><td>NB to WB</td><td>1</td><td rowspan="2">1320</td><td>>2800</td></tr>
<tr><td>SB to WB</td><td>1</td><td>>1600</td></tr>
<tr><td rowspan="2">Burr Street</td><td>NB & SB to EB</td><td>1</td><td>380</td><td>>900</td></tr>
<tr><td>NB & SB to WB</td><td>1</td><td>470</td><td>>650</td></tr>
<tr><td rowspan="4">Grant Street</td><td>NB to EB</td><td>1</td><td rowspan="2">490</td><td>>750</td></tr>
<tr><td>SB to EB</td><td>1</td><td>>1300</td></tr>
<tr><td>NB to WB</td><td>1</td><td rowspan="2">470</td><td>>1300</td></tr>
<tr><td>SB to WB</td><td>1</td><td>>900</td></tr>
<tr><td rowspan="4">Broadway</td><td>NB to EB</td><td>1</td><td rowspan="2">640</td><td>>850</td></tr>
<tr><td>SB to EB</td><td>1</td><td>>1300</td></tr>
<tr><td>NB to WB</td><td>1</td><td rowspan="2">650</td><td>>1300</td></tr>
<tr><td>SB to WB</td><td>1</td><td>>900</td></tr>
</table>

Operational Considerations

Ramp meters have a few basic elements that need to be considered during the planning and design phase. These include queue storage on the ramp and acceleration distance after the ramp meter signal. In addition, the underlying operation of the ramp metering system also needs to be considered. Key operational considerations related to these elements are as follows:

- Since ramp meters stop traffic and then let vehicles proceed, the need to provide queue storage is important. If during metering, queues extend along the ramp and onto the adjacent arterial roadway, this will cause congestion and lead to complaints from the adjacent municipalities. As part of the overall ramp metering system, queue detectors can be located along each entrance ramp near the extents of the available storage. When activated, the ramp metering rate can be increased to release a higher volume of ramp traffic which will reduce the length of the queue.

- With respect to acceleration distance, it is important that there is adequate acceleration distance provided to allow for safe and efficient merge operation along the freeway mainline. It is noted that for each entrance ramp where ramp meters are proposed, the entrance ramp is configured as an add lane / auxiliary lane. This configuration should provide flexibility to allow vehicles to accelerate to approximately highway operating speeds when the ramp meters are activated. However, further investigations during a future design phase are required to confirm that the ramp meter locations allow for adequate acceleration distance while still maximizing queue storage on the ramp.
- There are several adaptive algorithm options available for operation of the ramp metering system. However, using a similar adaptive algorithm throughout the state would provide consistency in terms of driver expectations, system operations, and maintenance.
- The selection of a central ramp metering system will depend on the full ATM software solution and the status of the ramp metering system currently being deployed in Indianapolis.

Physical Infrastructure Considerations

All of the ramps within the study corridor, that are proposed to be included within the ramp metering system, are configured as an add lane as they enter the I-80/94 corridor and remain an auxiliary lane until the next exit ramp. With this common ramp configuration, no major civil infrastructure changes are anticipated at any entrance ramp. However, other physical infrastructure considerations, specifically related to placement of the ramp meter signals, at each proposed interchange and individual entrance ramp are presented below:

Calumet Avenue Interchange: The northbound to eastbound and the southbound to eastbound entrance ramps merge together prior to entering the freeway facility. It is anticipated that the ramps can be metered together in the two lane section, using an alternating ramp metering sequence between the left and right lanes. The acceleration distance beyond the proposed ramp metering location is limited prior to traffic actually entering the freeway facility, although the two lane entrance ramp is configured as an add lane / auxiliary lane with the right lane merge located approximately 800 feet beyond the painted gore.

In the westbound direction, the two westbound entrance ramps merge together prior to entering the freeway as a single add lane / auxiliary lane. It is anticipated that each ramp would be metered separately with single lane ramp meters. Further investigation into the acceleration distance required for the northbound to westbound loop ramp noting that this ramp merges first into the physically separated weaving lane that also provides access to the westbound to southbound loop ramp.

Indianapolis Boulevard Interchange: The northbound to eastbound and the southbound to eastbound entrance ramps merge together prior to entering the freeway facility. It is anticipated that the ramps can be metered together in the two lane section, using an alternating ramp metering sequence between the left and right lanes. Similar to Calumet Avenue, the acceleration distance beyond the proposed ramp metering location is limited prior to traffic actually entering the freeway facility, although the two lane entrance ramp is configured as an add lane / auxiliary lane with the right lane merge located approximately 800 feet beyond the painted gore.

In the westbound direction, the two entrance ramps merge together prior to entering the freeway facility as a single add lane / auxiliary lane. It is anticipated that each ramp would be metered separately with single lane ramp meters, both of which could be located immediately prior to the merge point (physical gore) between the two ramps. It is noted that the northbound to westbound entrance ramp is not impeded by any westbound exit ramps, as is the configuration at Calumet Avenue, therefore acceleration issues should not be an issue.

The proposed location of the ramp meter signal on each ramp presents an opportunity to operate the ramp meters in an alternating sequence between the two ramps. However, actual placement of the ramp meter signals will require further investigation noting the limited distance between the freeway mainline and the northbound to westbound ramp at the proposed ramp meter location.

Kennedy Avenue Interchange: The northbound to eastbound and the southbound to eastbound entrance ramps merge together prior to entering the freeway facility. It is anticipated that the ramps can be metered together in the two lane section, using an alternating ramp metering sequence between the left and right lanes. Similar to Calumet Avenue and Indianapolis Boulevard, the acceleration distance beyond the proposed ramp metering location is limited prior to traffic actually entering the freeway facility, although the two lane entrance ramp is configured as an add lane / auxiliary lane with the right lane merge located approximately 700 feet beyond the painted gore.

In the westbound direction, the two entrance ramps merge together prior to entering the freeway facility as a single add lane / auxiliary lane. It is anticipated that each ramp would be metered separately with single lane ramp meters, both of which could be located immediately prior to the merge point (physical gore) between the two ramps. It is noted that the northbound to westbound entrance ramp is not impeded by any westbound exit ramps, as is the configuration at Calumet Avenue, therefore acceleration issues should not be an issue.

The proposed location of the ramp meter signal on each ramp presents an opportunity to operate the ramp meters in an alternating sequence between the two ramps. However, actual placement of the ramp meter signals will require further investigation noting the limited distance between the freeway mainline and the northbound to westbound ramp at the proposed ramp meter location.

Cline Avenue Interchange: The northbound to eastbound and the southbound to eastbound entrance ramps merge together prior to entering the freeway facility as a single lane. It is anticipated that the ramps can be metered together in the two lane section, using an alternating ramp metering sequence between the left and right lanes. The acceleration distance beyond the proposed ramp metering location is sufficient noting that the two lane ramp merges to a single lane prior to entering the freeway as an add lane / auxiliary lane.

Similar to the eastbound direction, the northbound to westbound and the southbound to westbound entrance ramps merge together prior to entering the freeway facility as a single lane. It is anticipated that the ramps can be metered together in the two lane section, using an alternating ramp metering sequence between the left and right lanes. The acceleration distance beyond the proposed ramp metering location is sufficient noting that the two lane ramp merges to a single lane prior to entering the freeway as an add lane / auxiliary lane.

Burr Street Interchange: The eastbound entrance ramp serves both the northbound and southbound arterial traffic from Burr Street through the south ramp terminal intersection. A single lane ramp meter is proposed to be located immediately west of the merge point (physical gore) between the entrance ramp and the freeway facility. The entrance ramp is configured as an add lane / auxiliary lane upon entering the freeway facility, therefore acceleration distance should be sufficient.

Similar to the eastbound direction, the westbound entrance ramp serves both the northbound and southbound arterial traffic from Burr Street through the north ramp terminal intersection. A single lane ramp meter is proposed to be located immediately east of the merge point (physical gore) between the entrance ramp and the freeway facility. The entrance ramp is configured as an add lane / auxiliary lane upon entering the freeway facility, therefore acceleration distance should be sufficient.

Grant Street Interchange: In the eastbound direction, the two entrance ramps merge together prior to entering the freeway facility as a single add lane / auxiliary lane. It is anticipated that each ramp would be metered separately with single lane ramp meters, both of which could be located immediately prior to the merge point (physical gore) between the two ramps. The proposed location of the ramp meter signal on each ramp presents an opportunity to operate the ramp meters in an alternating sequence between the two ramps. However, actual placement of the ramp meter signals will require further investigation noting the limited distance between the freeway mainline and the northbound to westbound ramp at the proposed ramp meter location.

The westbound entrance ramps are configured in a similar manner as the eastbound entrance ramps, therefore the same ramp meter signal locations and operation are anticipated.

Broadway Interchange: In the eastbound direction, the two entrance ramps merge together prior to entering the freeway facility as a single add lane / auxiliary lane. It is anticipated that each ramp would be metered separately with single lane ramp meters, both of which could be located immediately prior to the merge point (physical gore) between the two ramps. The proposed location of the ramp meter signal on each ramp presents an opportunity to operate the ramp meters in an alternating sequence between the two ramps. However, actual placement of the ramp meter signals will require further investigation noting the limited distance between the freeway mainline and the northbound to westbound ramp at the proposed ramp meter location.

The westbound entrance ramps are configured in a similar manner as the eastbound entrance ramps, therefore the same ramp meter signal locations and operation are anticipated.

> As will be discussed later in Section 4.4, geometric improvements are being considered at the Broadway Interchange and at the eastbound exit to I-65 south. These proposed changes, if implemented, will require relocation of the eastbound ramp meter signal to the loop ramp in the southwest quadrant.

Estimated Implementation Costs

For this strategy, as tailored for the study corridor, a high-level cost estimate has been prepared which includes several key elements such as the field devices, cabinets, power and communications, design and project management, and contingency. An estimate of the annual maintenance and operating costs for this system is also provided. More detailed costs, including quantities and unit costs, are provided in **Appendix B**.

Table 4.4: Ramp Metering System Implementation Costs

Civil Infrastructure	Cost (rounded)
Miscellaneous (guardrail, pavement patching, etc.)	350,000
Cantilevers	375,000
Lump Sum (MOT, CE, Clearing, Mobilization/Demobilization)	750,000
Civil Infrastructure - Subtotal	1,480,000
Systems	**Cost (rounded)**
Signal poles, heads, loops, cabling	280,000
Cabinets, controllers, handholes, power service, communications	560,000
Ramp metering software	150,000
Communications redundancy and protection of existing equipment	500,000
Integration and testing (5% of construction cost)	74,500
Systems Subtotal	1,570,000
Design (15%)	456,000
Project Management (5%)	152,000
Subtotal	**3,650,000**
Contingency (30%)	1,100,000
Total	**4,750,000**
Yearly operations and maintenance	172,000

4.1.4 Traffic Operations TSMO Strategy Combinations

With each individual improvement strategy in this category forming a plausible means to improve corridor traffic operations, each permutation or combination of the three TSMO strategies would also form a potential "strategy combination" where synergies could be realized and benefits increased. Exploring all of the permutations and combinations, a total of seven individual strategies and strategy combinations can be created from the three individual TSMO strategies as outlined in the table below:

STRATEGY COMBINATION	DESCRIPTION
	Ramp Metering
	Dynamic Shoulder Lanes
	Variable Speed Limit
SC1	Dynamic Shoulder Lanes + Ramp Metering
SC2	Dynamic Shoulder Lanes + Variable Speed Limits
SC3	Ramp Metering + Variable Speed Limits
SC4	Dynamic Shoulder Lanes + Ramp Metering + Variable Speed Limits

Analysis of each of these traffic operations related TSMO strategies and strategy combinations will be conducted and the results summarized in the subsequent sections of the report.

4.2 TRAFFIC SAFETY TSMO STRATEGIES

This section provides a general description of the scope, operating and / or physical considerations, and the implementation costs for several TSMO strategies that are primarily intended to address the identified **traffic safety** related issues. The traffic safety related TSMO strategies are:

- Dynamic Lane Control
- Variable Speed Limits
- Queue Warning

It is also recognized that these TSMO strategies can provide functionality beyond just addressing traffic safety related issues, noting that some of these strategies have already been introduced and discussed under the Traffic Operations TSMO Strategies section. Where applicable, these Traffic Safety strategies have also been considered as part of the other improvement strategies included under the Event Management category.

4.2.1 Dynamic Lane Control

Description

Dynamic Lane Control involves dynamically closing or opening of individual traffic lanes as warranted and providing advance warning of the closure(s) through the use of lane control signals, in order to safely merge traffic into adjoining lanes. In an ATM approach, as the network is continuously monitored, real-time incident and congestion data is used to control the lane use 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 Dynamic Shoulder Lanes strategy described above and would be used to indicate that the shoulder lane is open or closed for travel. In addition, this strategy would allow for the opening and closing of all the lanes to support needed maintenance and incident management.

For the application to the study corridor, recognizing the need for lane control over the inside and outside shoulder lanes, this strategy involves the use of full width gantry lane control across all of the freeway lanes and shoulders within the study limits. In addition to the lane control signals, the system would also include dynamic message signs to provide advanced warning for lane closures and the smooth transitioning of vehicles when approaching the closed lanes. The following diagram, **Figure 4.7** shows an example lane control system with variable speed limit signs.

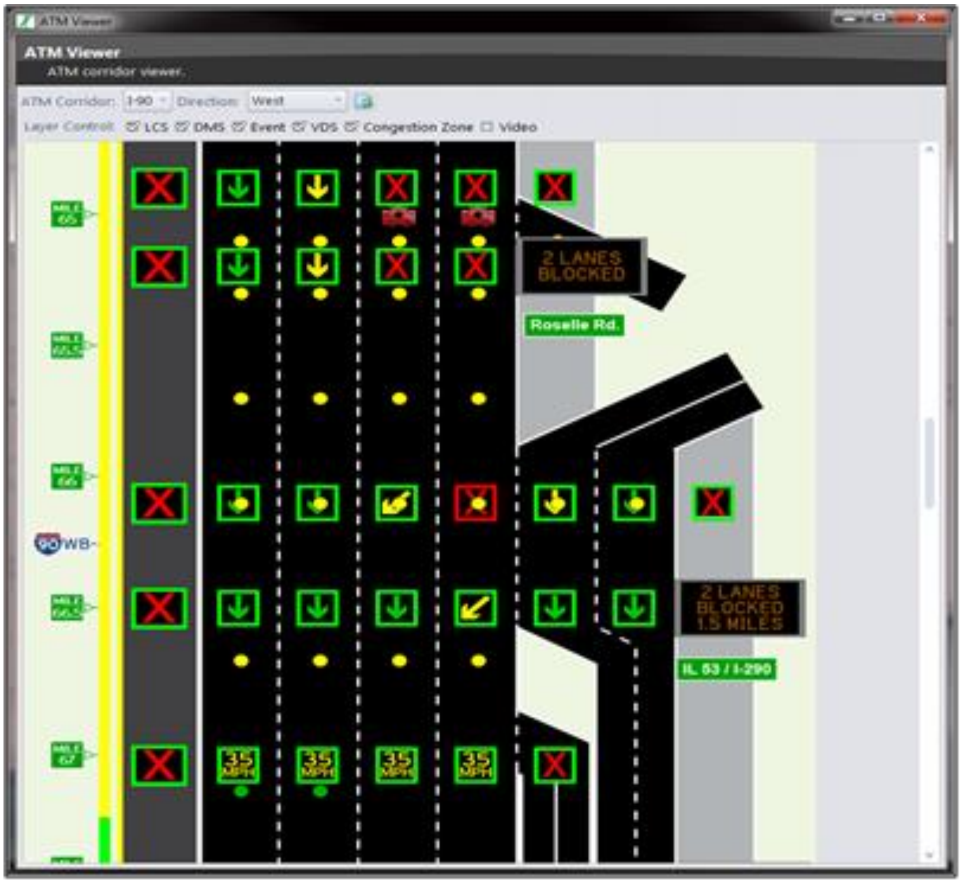


Figure 4.7: Sample Combined LC/VSL Signing Schematic (Illinois Tollway ATM Design)

The diagram above illustrates the layout of a combined lane control and variable speed limit signing scheme for a two-lane closure. As the figure only shows the area of the closure, additional queue warning and variable speed limit signs are included to step down speeds in advance of what is shown in this schematic layout.

For the study corridor, gantries supporting the lane control signals are anticipated to be placed at 0.5 mile intervals or spacings such that motorists can see the lane control signals on the next gantry as they pass under the previous gantry. This spacing is typical on major freeway facilities with long tangent sections and large radius horizontal curves. The actual location of each gantry will be confirmed in a subsequent design phase to ensure that there are no conflicts with the existing static signing that would increase visual clutter and create driver confusion. The approximate locations of the lane control gantries are shown in **Figure 4.8** for Indiana and **Figure 4.9** for Illinois. It is anticipated that several existing DMS could be used in conjunction with the lane control strategy to provide advance warning to motorists of an approaching lane closure.

Figure 4.8: Preliminary Lane Control Signal Gantry Locations in Indiana

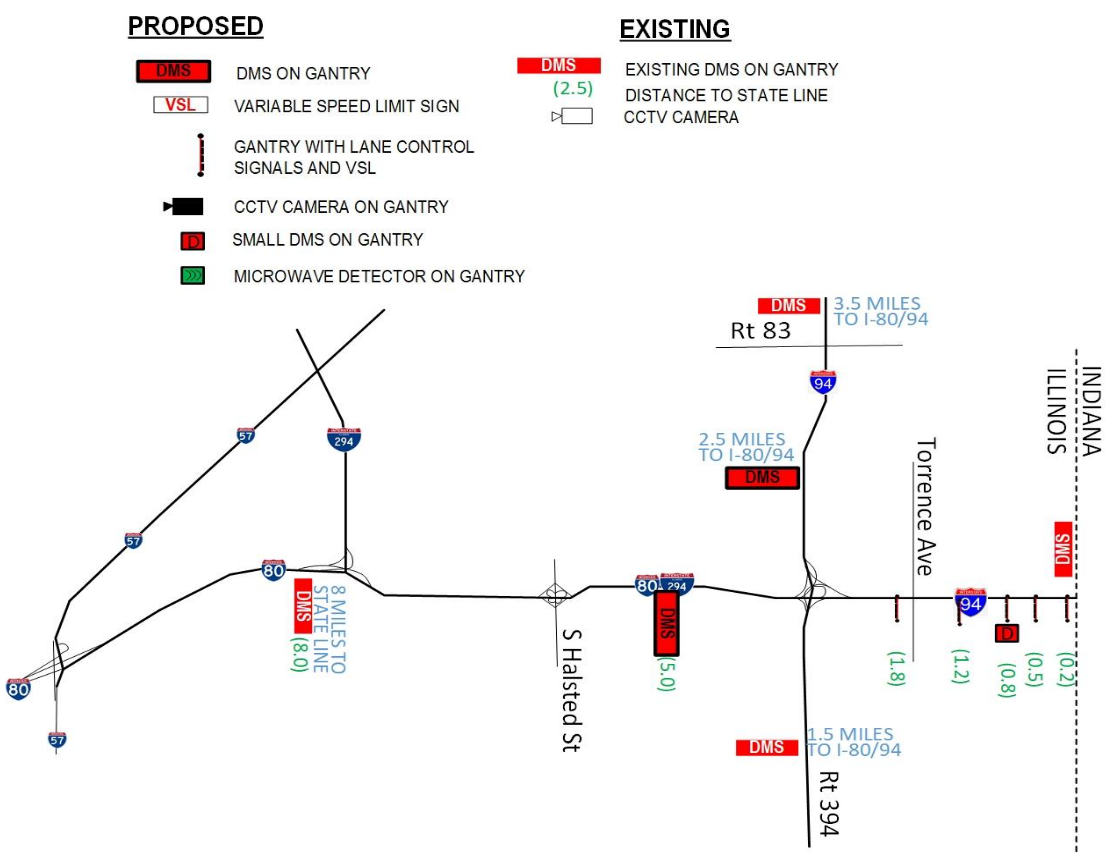


Figure 4.9: Preliminary Lane Control Signal Gantry Locations in Illinois

Key elements of the lane control strategy include:

- On the Indiana side, 58 new gantries are anticipated with placement at 0.5 mile intervals.
- On the Illinois side, five new gantries are anticipated in the eastbound direction with placement at half mile intervals approaching the Indiana border. No lane control gantries are proposed in the westbound direction in the segment of the corridor within Illinois.
- The existing DMS on I-94 and I-80 would be supplemented by two new DMS locations placed where they can provide relevant information to motorists as they approach the lane control system.
- The existing DMS on IL394 south of I-94 is currently located a sufficient distance in advance of the proposed lane control gantries to serve this purpose.

The system would provide for full remote control from the regional TMC and the Indianapolis TMC. The system would also provide for control of all gantries along the corridor in Indiana and Illinois.

Operational Considerations

Several operational considerations or features associated with the lane control strategy are presented below:

- Coordination of the overall lane control system with respect to the two road authorities is required to ensure that there is lane status continuity across the state line. It is noted that the status of any lane can differ in length depending upon the location of the incident or event
- The implementation of lane control signals in conjunction with other field devices such as variable speed signs will require further investigation as part of future design phase. However, it is anticipated that the chosen signs would provide flexibility in the ability to display both variable speed limit graphics and lane control graphics simultaneously
- Although there are existing detectors throughout the corridor, it is assumed that new vehicle detectors would be provided in each lane at each gantry location – assuming that the lane control system forms part of an ATM system with dynamic lane management. Integration with other potential TSMO strategies will allow use of a common set of vehicle detectors.

Physical Infrastructure Considerations

As indicated previously, the cross section for the majority of the corridor consists of four or five lanes with inside and outside shoulders that vary in width between 10 feet and 14 feet. Currently, there are several full gantries in both directions of the corridor to support directional signing and lane assignments for exit lanes. These existing gantries are all truss type structures without walkways for maintenance. Key considerations for the placement of lane control gantries in regards to the existing physical infrastructure include:

- Understanding that ideal gantry placement for lane control would allow for motorists to see the next gantry and lane control signals as they pass under the previous gantry, the placement of new gantries will need to be coordinated closely with the location of the existing gantries and other sign structures.
- The placement of new gantry supports in the median will require expansion of the median barrier by approximately 1.0 feet in each direction which will reduce the available cross section for other TSMO strategies such as dynamic shoulder lanes. In addition, the outside shoulder is frequently adjacent to a sound wall. Reconstruction of the sound wall in that area may be required to allow for the placement of the outside gantry support.
- Repaving of the Indiana portion of the study corridor is being proposed with construction likely in the 2035 to 2040 timeframe. Consideration should be given to ensure that any overhead sign structures being implemented as part of a TSMO project are designed to be compatible with the repaving project. It is understood that INDOT would like to bring all the mainline lanes back up to the standard 12’ width as part of the repaving project.

- Recognizing that the corridor crosses the state line and that lane control gantries are located in both jurisdictions, it is anticipated that approval will be obtained from both states to allow for a common gantry type throughout the study limits.

Lane control is expected to be one part of a combined TSMO strategy that may include dynamic shoulder lanes, variable speed limits, queue warning, and other enhanced ITS strategies. As a result, the lane control gantries will need to also support multiple DMS that form part of one or more complementary strategies.

Estimated Implementation Costs

For this strategy, a high-level cost estimate has been prepared which includes several key elements such as field devices, gantries, communications, power, civil works, design and project management, and contingency. An estimate of the annual maintenance and operating costs for this system is also provided. More detailed costs, including quantities and unit costs, are provided in Appendix B.

Table 4.5: Lane Control System Implementation Costs

Civil Infrastructure	Cost (rounded)
Superelevation Correction	3,680,000
Pavement Improvements (Alternative 3)	1,780,000
Drainage Improvements (Alternative 5)	1,800,000
Lump Sum (MOT, CE, Clearing, Mobilization/Demobilization)	14,800,000
Civil Infrastructure - Subtotal	22,000,000
Systems	**Cost (rounded)**
Gantry structures and foundations	13,900,000
Gantry equipment/cabling	1,580,000
Lane control signs	6,620,000
CCTV cameras	512,000
Cabinets, handholes, power service, communications	3,960,000
Central ATM software	350,000
Communications redundancy and protection of existing equipment	500,000
Cantilever Structures and Foundations (Wentworth)	170,000
Cantilever equipment/cabling	16,000
Lane control signs (Inside shoulder only)	30,000
Dynamic message sign on new dedicated gantry	230,000
DMS gantry structure and foundation	440,000
Integration and testing (2% of construction cost)	565,000
Systems Subtotal	28,900,000
Design (10%)	5,090,000
Project Management (5%)	2,550,000
Subtotal	**58,500,000**
Contingency (30%)	17,600,000
Total	**76,000,000**
Yearly operations and maintenance	787,000

4.2.2 Variable Speed Limits

This strategy is the same as described under the Traffic Operations TSMO Strategy section above. However, the intent of the strategy under this category is to address safety concerns where speed limits would be adjusted based on roadway incidents, events, work zones, and/or weather conditions, to maintain smooth traffic flow and to reduce the risk of collisions due to speed differentials. The placement of variable message signs would be the same as described previously. As such, a similar implementation cost estimate applies.

4.2.3 Queue Warning

Description

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, thus improving traffic safety by reducing the potential for rear-end crashes or other secondary incidents. In an ATDM approach, as the traffic conditions are monitored continuously, the warning messages are dynamically displayed based on the location and severity of the queues and slowdowns detected. Queue warning is frequently deployed in coordination with variable speed systems.

The potential locations for the small informational dynamic message signs (DMS) are shown in **Figure 4.10** for the segment of the corridor in Indiana. These small DMS would supplement the existing DMS in the corridor with placement of at least one sign anticipated between each interchange. If combined with another TSMO strategy where full width gantries are provided, the queue warning DMS could be located on the right side of every third gantry which would equate to a 1.5 mile spacing. An example of this mounting approach is shown in **Figure 4.11.** These signs could also be mounted on butterfly structures off the shoulder, like the signs planned for the I-465 TSMO project. This configuration affords the opportunity to provide more detailed queue warning information.

Figure 4.11: Example of Queue Warning DMS

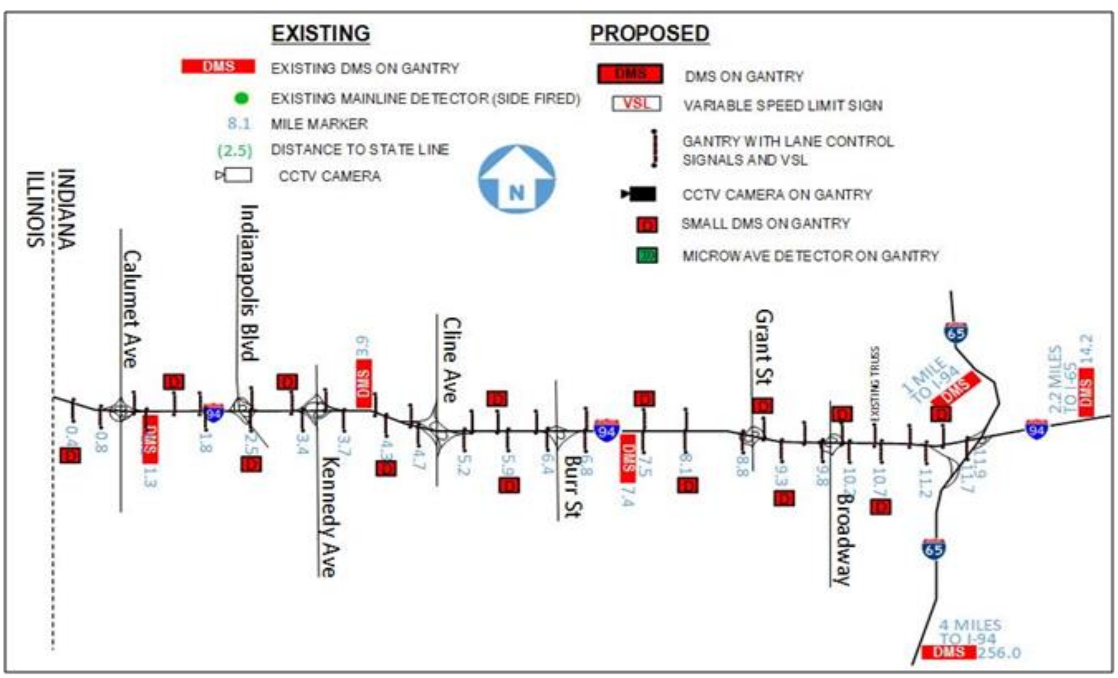


Figure 4.10: Potential Locations for Queue Warning Informational DMS

Operational Considerations

A connected and integrated system would provide the best response for queue warning and many of the other TSMO strategies. A number of operational considerations have been identified with respect to the queue warning system as listed below:

- Any existing full size DMS in the study limits should become accessible through the ATM module to display supporting messaging.
- Queue and event information should be available to all the agencies in near real time. This ability to share information on queue and event information can be in the form of an integrated single system for the region or interfaces between existing agency systems. Given that significant events in this area can cause traffic backups well beyond the study limits, queue management served through a near real time system interface between the agencies is suggested.
- Agencies would need to develop coordinated response plans to ensure consistent response and messaging throughout the region.
- Queue lengths would only be dynamically monitored within the study limits through the implementation of new vehicle detection. Queues that extend beyond the study limits would need to be monitored by other means by the responsible agency.
- Considering that many of the queues that originate in the corridor will be related to a roadway event, queue warning messaging would need to be coordinated with event management signing, dynamic shoulder lanes, lane control, and variable speed limit systems, if implemented.

Currently, INDOT, IDOT, ISTHA and ITR are not physically connected via a fiber network and each agency operates its own ATMS. However, information is shared between these agencies via the Lake Michigan Interstate Gateway Alliance (LMIGA). 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.
The Project team and partnering agencies will need to determine if it is appropriate to share corridor details and coordinate responses through the LMIGA network or direct Center-to-Center interfaces between the cooperating agencies. If communications between the systems continues to flow through the LMIGA platform, changes to the LMIGA Gateway system may be required to adequately support a coordinated queue warning response across the agencies.

Physical Infrastructure Considerations

The following are physical infrastructure considerations that will need to be addressed to implement a queue warning system within the study corridor:

- Foundations for side mounted sign structures would require modifications to the median barrier. Foundations for full width gantries would also require modifications to the median barrier. The modifications to the barrier to accommodate placement of new gantry supports in the median will require expansion of the median barrier by approximately 1.0 feet in each direction which will reduce the available cross section for other TSMO strategies such as dynamic shoulder lanes. In addition, the outside shoulder is frequently adjacent to a sound wall. Reconstruction of the sound wall in that area may be required to allow for the placement of the outside gantry support.
- Full width gantries would be used for a lane control system; therefore, these gantries would be available to mount the queue warning dynamic message signs if both strategies are selected.

- The current microwave vehicle detection in the corridor is old and several, if not all the locations, may need to be updated or replaced. If multiple TSMO strategies are selected, the queue warning system would be able to use the same vehicle detectors such as the mainline detection related to the ramp metering strategy.

Estimated Implementation Costs:

For this strategy, as tailored for the study corridor, a high-level cost estimate has been prepared which includes several key elements such as the field devices, cabinets, power and communications, design and project management, and contingency. An estimate of the annual maintenance and operating costs for this system is also provided. More detailed costs, including quantities and unit costs, are provided in Appendix B.

Table 4.6: Queue Warning System Implementation Costs

Civil Infrastructure	Cost (rounded)
Lump Sum (MOT, CE, Clearing, Mobilization/Demobilization)	3,300,000
Civil Infrastructure - Subtotal	3,300,000
Systems	**Cost (rounded)**
Butterfly Mounted DMS	3,260,000
Cabinets, Handholes, Power Service, Communications	927,000
Queue Warning Software	250,000
Center to Center Integration	100,000
Communications Redundancy and Protection of Existing Equipment	500,000
Dynamic message sign on new dedicated gantry	230,000
DMS gantry structure and foundation	440,000
Integration and testing (2% of construction cost)	115,000
Systems Subtotal	5,820,000
Design (10%)	912,000
Project Management (5%)	456,000
Subtotal	**10,500,000**
Contingency (30%)	3,150,000
Total	**13,700,000**
Yearly operations and maintenance	117,000

4.3 EVENT MANAGEMENT TSMO STRATEGIES

This section provides a general description of the scope, operating and / or physical considerations, and the estimated implementation costs for several TSMO strategies that are primarily intended to support the efficient management of events within the study corridor in order to reduce further delays and improve traffic safety. The event management related TSMO strategies are:

- Maintenance and Operation Enhancements
- Complementary Strategies
- Work Zone Management

Several Traffic Operations and Traffic Safety related strategies also form part of many of the event management strategies described below, noting that the event management strategies largely rely on the field devices and systems related to these other strategies to effectively manage traffic during a planned or unplanned event within the study corridor.

4.3.1 Maintenance and Operations Enhancements

A common theme with most of the stakeholder interviews was the importance of, and difficulties related to roadway operations and maintenance on the Borman, in the project area. With the traffic demand and truck volumes, even minor issues along the roadway can quickly lead to significant backup. In addition to the system related strategies discussed above, it is important, and cost effective, to look at opportunities to improve, upgrade and fine tune operational and maintenance practices. Based on the interviews, field reviews and existing practices, the following potential operational upgrades and refinements have been identified.

Towing and Recovery Incentive Program (TRIP)

Description

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 response by towing operators to incidents involving heavy commercial vehicles and provides a monetary incentive to the towing operator to arrive on-scene within a specified period of time (typically in the range of 30-45 minutes depending upon location); clear the incident within a specified period of time (typically 90 minutes); and to 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.

> These goals align with those of INDOT as they relate to safety and to implementing innovative strategies that save lives.

The setup and operation of a new TRIP along I-80/94 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.)

Estimated Implementation Costs

Assuming a monetary incentive of $2500 per successful TRIP event ($3500 if specialized additional equipment is required) and based upon the incident, figures provided (approximately 4800 incidents over three years; 38% involving commercial vehicles; 20% of those commercial vehicle incidents blocking lanes), Parsons assumes 8-10 TRIP events per month in this corridor that would generate incentive payments of $270,000 annually.

Program deployment is estimated at $125,000 over a six-month schedule and program management during operation is estimated to be approximately $160,00 for a 12-month term. The total cost of an 18-month term, including incentive payments, is estimated to be approximately $550,000. It should be noted that several jurisdictions are successfully charging the incentive payment back to the responsible party. If this approach is included in the application of TRIP within the study corridor, the overall program cost could be reduced to $285,000 for 18 months. For the purposes of this study, an annual cost for this program is estimated to be approximately $365,000.

Enhanced Hoosier Helper Program

Description

Currently Hoosier Helpers patrol interstates including the I-80/94 from the Illinois State Line to I-90. They assist motorists, and keep 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. The Hoosier Helpers are also a valuable asset to numerous agencies including the Indiana State Police and local first responders in assisting with various emergencies on Indiana interstates. Each Hoosier Helper personnel are trained in First Aid, CPR, the use of an Automatic External Defibrillator (AED), HAZMAT, and have completed medical helicopter training.

Under the current program the Hoosier Helper vehicles do not have the ability to tow disabled vehicles. In an effort to minimize clearance times on 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 Hard Shoulder prior to opening – as required.

Hoosier Helpers currently operate five days a week during the peak periods and sometimes six days per week when needed. Consideration should be given to expanding the hours that the Hoosier Helpers are available to help ensure the roadway and shoulders are clear. Some of the respondents to the stakeholder interviews recommended that the Hoosier Helper Program should be expanded to 24/7 on the study corridor. Alternatively, providing these additional services separately from the Hoosier Helper program may be simpler with the most appropriate approach to be determined in the subsequent design phase – if this maintenance and operations enhancement strategy is selected for implementation.

Estimated Implementation Costs

The Hoosier Helper program is currently sponsored by Geico. However, any changes to the program would only involve approval from INDOT (Division of Traffic Management) and any additional costs associated with these changes would be attributed to INDOT. For the purposes of this study, an annual increase in operating costs of approximately $365,000 was assumed based on the need for two additional drivers operating 16 hours /day.

4.3.2 Complementary Strategies

Common to many ATMS deployments, the following are complementary operational and system strategies that can enhance the effectiveness of the key TSMO strategies described above. These complementary strategies leverage the devices and infrastructure that would be deployed to support the key TSMO strategies with limited additional costs.

In this section, each complementary strategy is described in terms of how they are anticipated to fit within the study corridor as well as how they may be expanded to support the corridor needs. However, to provide context with the potential fit of these complementary strategies, the current TMC operations and ATMS employed by INDOT is described first.

System Context

INDOT currently operates two Traffic Management Centers (TMC), one in Indianapolis and one in Gary. The Indianapolis TMC is the only center that operates 24/7/365. This TMC 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 TMC in Indianapolis 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 this TMC.

The Gary TMC currently operates from 6:00 am to 10:00 pm and is typically staffed with two operators. The operations staff are contracted employees, procured through an operations support contract. They TMC staff manage and operate the ITS devices in the region, dispatch Hoosier Helpers, and coordinate between emergency response agencies (e.g. law enforcement, fire department, etc.) and the state 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 and IRIS (Intelligent Roadway Information System) systems. Iron Mountain is the INDOT legacy ATMS and is used to enter event details through the Global Event Manger (GEM). All activities 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 project developed by the Minnesota Department of Transportation. The ATMS is an integrated platform used by transportation agencies to monitor and manage interstate and highway traffic as well as to manage traffic monitoring and control devices. The IRIS software presents a map-based interface to system operators and is currently used to view and control the CCTV within the region.

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

The Gary TMC currently coordinates with 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.

Complementary Strategy Descriptions

Provide Optimal ITS Device Deployment. If INDOT installs gantries and ITS equipment and communications required to support the ATM strategies described above, optimal ITS devices, systems, and inter-agency connections should be provided to improve event management, road weather management, active demand management, and traffic surveillance. In addition to optimizing ITS device deployment, two additional RWIS stations could be considered to improve the accuracy of the automated weather responses that will in turn improve safety and minimize delays resulting from weather related accidents. Additional RWIS stations would also assist in supporting decisions related to when the dynamic shoulder lane can be safely implemented.

Leverage VSL and Queue Warning Equipment: The VSL and Queue Warning strategies will require more vehicle detection stations throughout the corridor. This added vehicle detection can also be used to provide very timely and more accurate travel times through corridor. These travel times could be used to drive DMS travel time messages and ATIS feeds as well as providing relevant information to adjacent agencies (e.g. transit) to support Active Demand Management strategies and to encourage broader alternative routes or modes during times of significant congestion.

Optimize Data and Image Sharing: Dynamic shoulder lane functionality will require additional CCTV cameras to provide sufficient coverage that will permit rapid confirmation of the shoulder conditions throughout the corridor such the shoulders are safe to open for vehicle travel. The use of these cameras should also be leveraged to help optimize all event responses by making camera images available to the TMC, INDOT maintenance, and Indiana State Police Dispatch which in turn will support faster and more accurate responses. Sharing camera images with IDOT, Illinois Tollway and the Indiana Toll Authority should also be considered.

Center to Center Interfaces: The full ATMS solution would include full comprehensive near real time sharing of traffic and event data, as well as camera images between INDOT, IDOT, Illinois Tollway, and the Indiana Toll Authority. The I-90/94 corridor is a major connector between these road authorities and significant issues in the corridor can have a large impact on traffic throughout the larger region. Rapid and accurate coordination between the agencies can significantly reduce impacts and help motorists make good decisions relating to their travel.

Within the immediate stud area, there are very limited alternate routes that could readily be used for integrated corridor management (ICM) strategies without a very significant investment. However, there are alternate routes outside the study limits that may be appropriate alternatives when there are significant events detected on the I-80/94 corridor. A near real time interface with adjacent systems will allow these other systems, using traffic or event data from the study corridor, to promote the use of these alternatives when significant congestion detected.

Computer Aided Dispatch (CAD) Integration. Given the high traffic volumes and 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. It is noted from other agency experience that ATMS CAD integration is proven to be an effective measure in minimizing response and clearance times.

Maintenance and Emergency Response Agency Access to CCTV: As part of the dynamic shoulder lane system, CCTV coverage is anticipated to be enhanced to ensure full coverage of the entire roadway, including shoulders, throughout the study corridor. Currently INDOT Maintenance does not have access to the INDOT cameras. This strategy would involve providing CCTV access to maintenance and potentially other emergency response agencies which will allow these responders the opportunity to review the conditions in advance of responding to the event. This potentially critical information will result in more accurate initial responses as opposed to current procedures that typically involve getting a person on scene and then coordinating a second response to get the appropriate crews in the field.

Advanced Transit Operations Integration. The strategy would involve the integration between major transit agencies in the region to allow corridor condition information to be shared seamlessly. Under significant congestion events, rapid access to corridor conditions related data (event and traffic delays) will provide the transit agencies with the ability to promote the use of the transit options. While bus transit is not a major contributor to people movement alternatives within the corridor, there are viable rail options available. Coordination with and promotion of these options does not add any significant costs to the strategy.

Implementation Costs

Provide Optimal ITS Device Deployment. The ATM strategies discussed above will provide a significant amount of additional equipment. The costs to integrate the new equipment into the full ATMS responses are discussed 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 Data from New Field Equipment. If an "off-the-self" ATM central software is selected, an interface between the existing ATMS platform would allow for the sharing of data from the new ATM field equipment. Typically, an ATM platform would support a "standards-based" interface, however, some costs should be expected on both sides to work through integration details and perform integration testing. To address the potential interface requirement to leverage data from the new field equipment, an allowance for integration and testing in the range of $50,000 to $100,000 should be considered.

Optimize Data and Image Sharing. Leveraging the added camera images to make these available to the TMC, INDOT maintenance, Indiana State Police Dispatch, IDOT, Illinois Tollway, and the Indiana Toll Authority will require communications connections between the systems and a means to share video in a controlled manner. Assuming that the current ATMS or a selected ATM Platform allows for video sharing between agencies (with appropriate controllable rights), a cost of approximately $50,000 is estimated to set up and configure the system as well as provide general training to the involved agencies. Approximate costs to connect the agencies is discussed below.

Center to Center Interfaces. There are two primary costs associated with providing interfaces between the agency ATMS operations, physical connection and system interface development and integration. Both agencies have fiber networks that are either adjacent or very close to each other, therefore the physical connections costs are anticipated to be approximately $25,000 for ISTHA, $50,000 for the Indiana Toll Authority, and approximately $100,000 for IDOT. Costs for system interfaces can vary, with typical costs of approximately $50,000 per side per interface. Overall, the costs could range between $150,000 to $250,000 assuming that INDOT would have one interface that can support IDOT, ITA and ISTHA.

Computer Aided Dispatch (CAD) Integration. Integration costs can vary depending on the 911 CAD system and the nature of the interface (one-way or two-way). The costs also depend on if the ATM is already designed to accept events from external systems. Based on the current understanding of the existing CAD and ATM(S) systems, the integration cost is anticipated to be approximately $150,000.

Advanced Transit Operations Integration. Once a standards-based center to center (C2C0 interface is available within the ATM(S), access could also be made available to transit agencies to provide event and traffic delay information associated with the I-80/94 corridor. Responses that promote transit alternatives could be built into the ATM or ATMS without any significant additional costs. More complicated coordinated responses could be considered but given the limited transit alternatives within the broader study area, the additional effort and costs may not be justified and have therefore not been included at this time. Total costs for integration would be expected to be approximately $50,000 assuming that system integration costs at the transit agency would be the responsibility of the transit agency.

Maintenance and Emergency Response Agency Access to CCTV: There is no significant additional cost to allow maintenance and emergency response personnel access to the CCTV as long as they are on the network. Total costs would be expected to be approximately $50,000.

A summary of the cost estimates for all of the complementary strategies is provided below in **Table 4.7.** Where a range was shown above, the higher costs were included in the summary table to be conservative.

Table 4.7: Complementary Strategy Cost Estimate Summary

STRATEGY	COST
Provide Optimal ITS Device Deployment	$250,000
Leverage Data from New Field Equipment	$100,000
Optimize Data and Image Sharing	$50,000
Center to Center Interfaces	$250,000
Computer Aided Dispatch (CAD) Integration	$150,000
Advanced Transit Operations Integration	$50,000
Maintenance and Emergency Response Agency Access to CCTV	$50,000
Total Cost of Complementary Strategies	**$900,000**

4.3.3 Work Zone Management

Description

Work zones play a key role in maintaining and upgrading the road network. Unfortunately, daily changes in traffic patterns, narrowed rights-of-way, and other construction activities often create a combination of factors resulting in crashes. These crashes also cause excessive delays, especially given the constrained driving environment found on the I-80/94 corridor.

As indicated in the previous section, other aspects of an overall event management strategy will provide infrastructure that help support work zone management. An effective work zone management system should provide the following specific functionality:

- The variable speed limit (VSL) system modules should allow operators to set maximum speeds throughout a work zone and use the same step-down logic as used for the variable speed limits system to slow traffic prior to the work zone.
- Lane control signals 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 enter 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 related lane closure(s).
- The system should allow for automated advanced DMS messaging that provides motorists 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 system should provide the ability to manage and store work zone and maintenance contacts for easy access by the operators.
- The system should provide adequate detection to monitor work zone speeds and approximate end of queues within the corridor.
- The system should provide an interface to adjacent ATMS to pass work zone details and allow for advanced signing through the other ATMS.

Operational Considerations

Through the development of the TSMO strategies for the study corridor, several key stakeholders were consulted with respect to current operation and maintenance procedures and policies. The ability to continue to provide safe and efficient roadway maintenance was a key issue that was raised by many stakeholders. The cleaning of drainage inlets, snow and debris removal were identified as key considerations. The significant traffic volumes throughout the day coupled with heavy truck traffic adds to the importance of maintaining safe and efficient work zones in the corridor.

Physical Infrastructure Considerations

There are no significant physical infrastructure considerations associated with this strategy.

Estimated Implementation Costs

The current INDOT systems do support Work Zone management and incident management. However, with HSR, Lane Control, VSL Queue Warning and Ramp Metering, there is an opportunity to provide a more advanced solution as described above. Work Zone management would typically form part of any new ATM software used to manage the strategies identified above. Adding the appropriate work zone management support to the system may cost between $50,000 and $150,000 above the basic ATM functionality.

4.4 NON TSMO CORRIDOR IMPROVEMENTS

In addition to the primarily technology based TSMO strategies described above, other corridor improvements have been identified to address several traffic operations issues identified through the analysis of the existing and future conditions. These other improvements include geometric changes and enhancements to the existing guide signing along the corridor, both of which are described in more detail below.

4.4.1 Broadway Interchange and I-65 Interchange Modifications

Description

Potential modifications at the Broadway Avenue interchange and the I-65 interchange have been identified to assist in alleviating congestion for eastbound I-80/94 traffic that results from the various traffic operations related issues identified in Section 3. The proposed interchange ramp modifications include:

- The south ramp terminal intersection will be modified to allow northbound Broadway traffic to access eastbound I-80/94 through a left movement onto the existing loop ramp. This modification eliminates the need for the northbound Broadway to the eastbound I-80/94 entrance ramp.
- As part of this proposed change, eastbound I-80/94 will be provided with an additional through lane at the Broadway exit ramp. This additional lane will be placed on the outside shoulder and the exit ramp will be configured as a tapered exit ramp. It is noted that an Interstate Access Request would need to be required to modify the Broadway interchange and a Level 1 design exception would be required for to permit the reduced shoulder width that would result over a portion of the new travel lane on I-80/94. Figure 4.12 and Figure 4.13 graphically depict the proposed modifications.at the Broadway interchange.
- In conjunction with the proposed Broadway interchange modifications, the eastbound I-80/94 exit ramp to southbound I-65 is proposed to be reconfigured to accommodate an additional ramp lane. The existing ramp configuration consists of two ramp lanes, however, traffic analysis has shown that the second or outside ramp lane is underutilized. Visual observations have confirmed the analysis findings in that a large number of trucks will queue within this inside ramp lane and will not move into the second or outside ramp lane, or allow for gaps for motorists to move over, resulting in the underutilization.

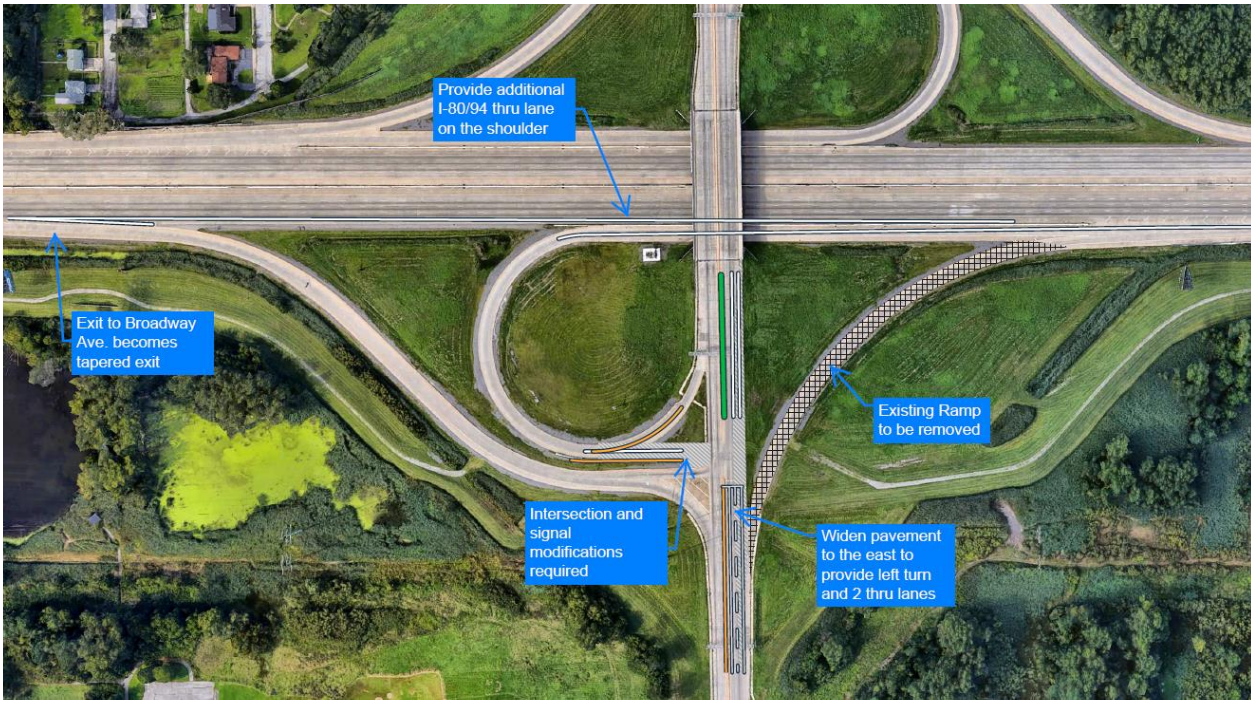


Figure 4.12: Broadway Avenue and I-80/94 Proposed Interchange Modifications

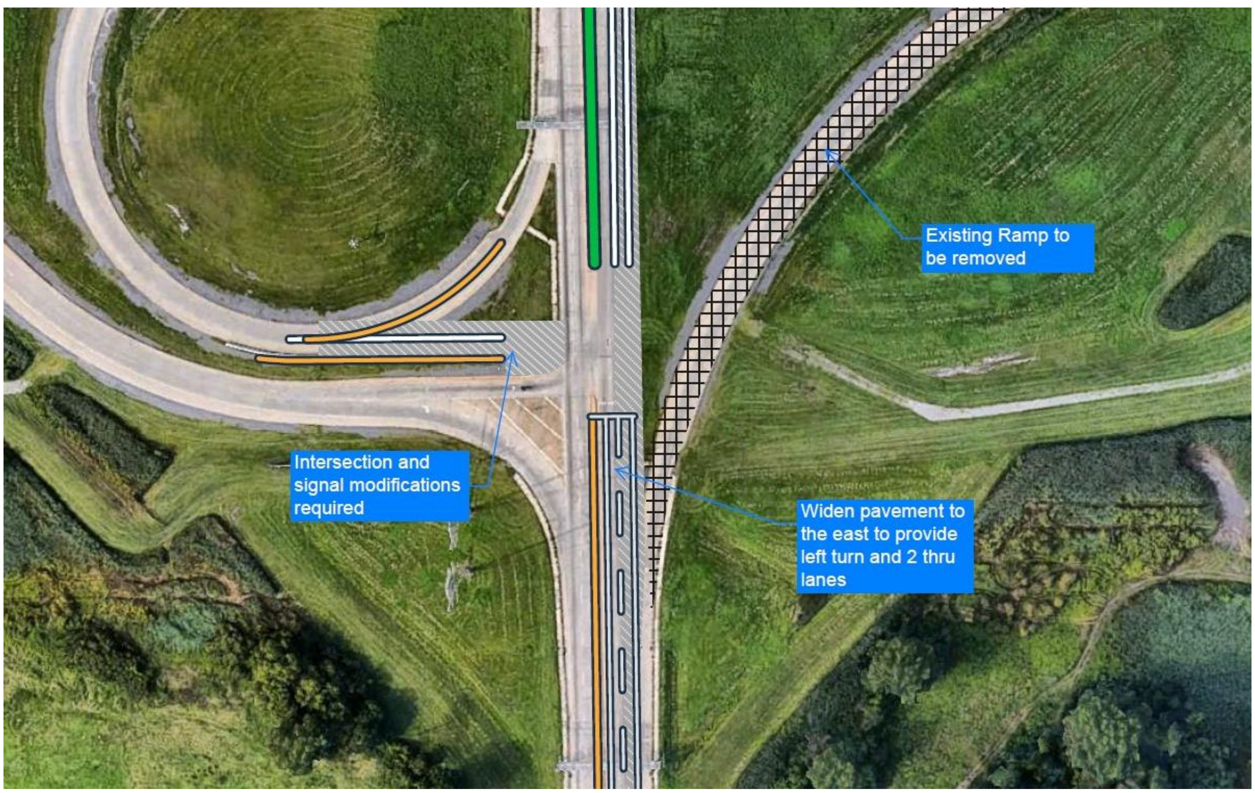


Figure 4.13: Broadway Avenue and I-80/94 Proposed Interchange Modifications

- With the removal of the northbound Broadway to eastbound I-80/94 ramp, the right two lanes on the mainline can be utilized for the exit to southbound I-65.
- Traffic will be shifted outward, utilizing the existing ramp pavement, which will allow the eastbound I-80/94 left lane to widen from one lane to two lanes. The middle lane will be configured as an exit option lane that will ultimately allow for the southbound exit to operate as three lanes and the eastbound mainline to maintain four through lanes. Refer to **Figure 4.14** and **Figure 4.15** for additional details.

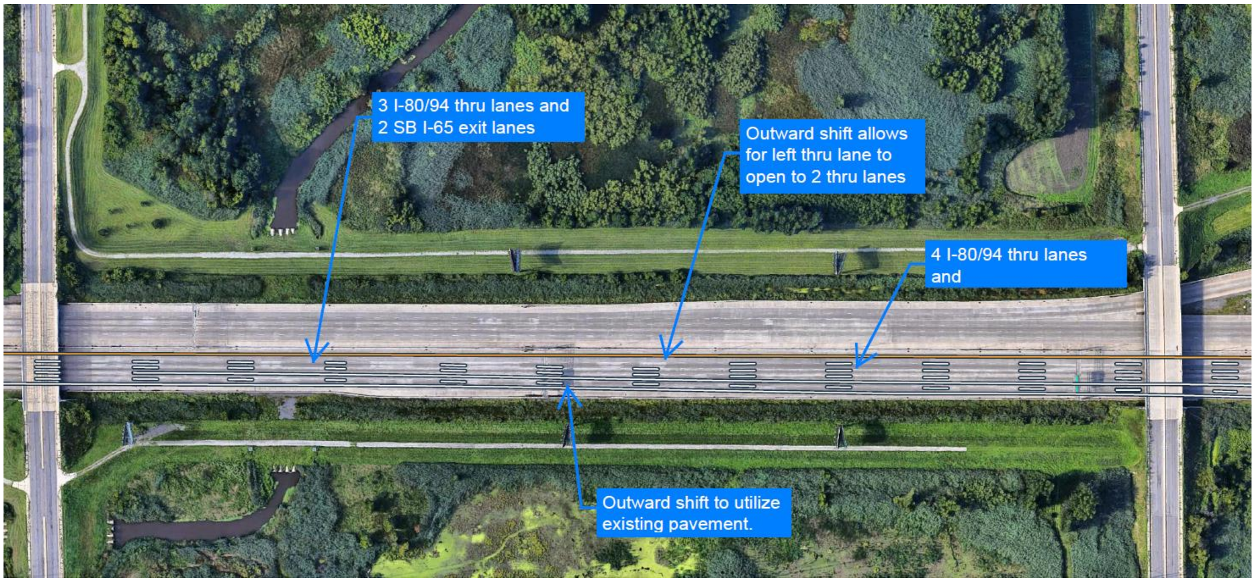


Figure 4.14: Segment of I-80/94 Corridor Showing the Outward Shift of the Travel Lanes

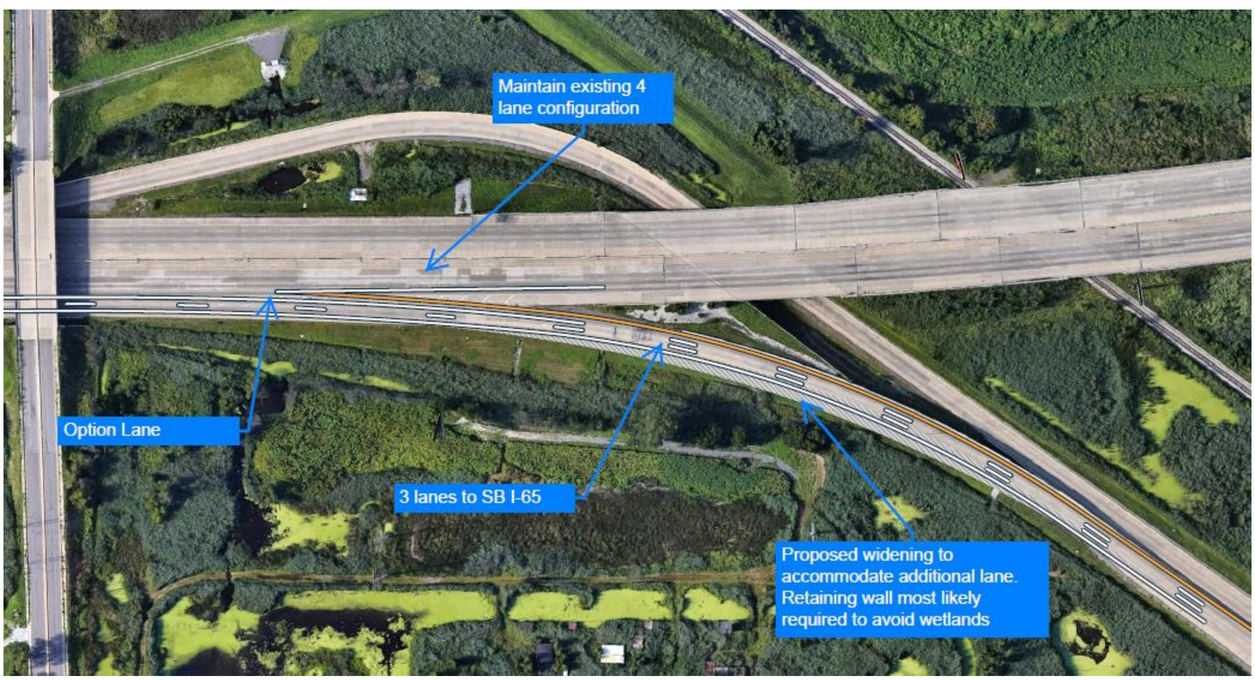


Figure 4.15: Broadway Avenue and I-80/94 Proposed Interchange Modifications

Estimated Implementation Costs

The proposed costs for this geometric change include intersection and traffic signal changes to the south ramp terminal intersection on Broadway, an additional travel lane for eastbound I-80/94 in the shoulder (pavement reconstruction) within the interchange, and additional work to provide a third exit lane for the exit ramp to I-65 southbound.

Table 4.8: Implementation Costs for Proposed Broadway Interchange and I-65 Interchange Modifications

Civil Infrastructure	Cost (rounded)
Lump Sum (MOT, CE, Clearing, Mobilization/Demobilization)	250,000
Exit Ramp to SB I-65	1,110,000
EB I-80/94 Shoulder Work	1,050,000
Broadway Ave Interchange	375,000
Civil Infrastructure - Subtotal	2,770,000
Design (10%)	277,000
Project Management (5%)	139,000
Subtotal	**3,190,000**
Contingency (30%)	956,000
Total	**4,150,000**

4.4.2 Signing Enhancements

Throughout the detailed analysis of the study corridor as part of the existing and future conditions analysis, as well as from input provided by the various study stakeholders, several enhancements to the existing guide signing along the corridor are suggested. These enhancements include:

- Additional Guide Signs (Warning Signs) in advance of the eastbound lane reduction at the eastern limits of the study area.
- The addition of interchange sequence signs.

Additional Warning Signs (Eastbound Lane Reduction)

To address the lack of advisory signing approaching the existing left lane merge at the eastern limits of the study corridor, additional warning signs are proposed.

Currently, only a shoulder mounted Left Lane Ends (with 1000 ft tab) warning sign and a Lane Ends warning sign are located in the median to provide advance warning to motorists of the approaching unconventional left lane merge. In recognition of the size of these signs, motorists may miss viewing these signs noting the other major guide signing structures in the area.

To improve operations in advance of the physical taper, noting that slow speeds and congestion have been frequently observed in this area, three overhead warning signs at 1.0 mile, 1/2 mile, and at the taper point are proposed. These signs should be located over the left lane and indicate (black on yellow warning sign) that the lane is ending and that traffic should merge right.

Suggested text is provided below:

LEFT LANE ENDS 1 MILE	LEFT LANE ENDS 1/2 MILE	LEFT LANE ENDS MERGE RIGHT ↗

The approximate cost to install the three advance warning signs is summarized in **Table 4.9** below.

Table 4.9: Lane Drop Signage Costs

Civil Infrastructure	Cost (rounded)
Lump Sum (MOT, CE, Clearing, Mobilization/Demobilization)	125,000
Signage	275,000
Civil Infrastructure - Subtotal	400,000
Design (10%)	40,000
Project Management (5%)	20,000
Subtotal	**460,000**
Contingency (30%)	138,000
Total	**598,000**

Interchange Sequence Signs

The application of interchange sequence signs within the study corridor could improve traffic operations in both directions by potentially reducing lane changing as well as achieving better lane utilization. Approaching and between the system interchanges at I-65 and I-94, interchange sequence signs could be placed between interchanges to provide advance notice to drivers of the next three or four cross streets / interchanges – with the distances to each cross street provided. Noting the number of lanes within the study corridor, and the high percentage of truck traffic, these interchange sequence signs should be located over the lanes.

A total of 16 interchange sequence signs would be required, eight in each direction of travel. The first sign in the westbound direction would be located between the I-65 northbound entrance ramp and the exit ramp to Broadway, whereas in the eastbound direction, the first sign would be located prior to the Torrence Avenue exit ramp.

The approximate cost to install the 16 interchange sequence signs is summarized in **Table 4.10** below.

Table 4.10: Interchange Sequence Sign Costs

Civil Infrastructure	Cost (rounded)
Lump Sum (MOT, CE, Clearing, Mobilization/Demobilization)	1,300,000
Signage	1,120,000
Civil Infrastructure - Subtotal	2,420,000
Design (10%)	242,000
Project Management (5%)	121,000
Subtotal	**2,780,000**
Contingency (30%)	832,000
Total	**3,610,000**

Section 5 – IMPROVEMENT STRATEGY ASSESSMENT APPROACH

To assess each TSMO and non-TSMO strategy presented in the previous section, a set of assessment criteria have been identified for each category of improvement strategies. The criteria have been selected to reflect the intended function of the strategies; therefore, the assessment criteria and methodologies differ between the improvement strategy categories. The criteria have also been developed to quantify the potential benefits where possible, or otherwise to provide a qualitative assessment based on engineering judgement and examples from other jurisdictions.

The selected criteria and methodologies are described in this section with respect to each improvement strategy category.

5.1 TRAFFIC OPERATIONS TSMO STRATEGIES

Given the need to fully understand the performance of the traffic operations along the freeway and to evaluate the potential TSMO strategies, targeted assessment criteria were developed and extracted from the traffic operations micro-simulation model developed for the study area. Two distinct levels of analysis were considered, network level and corridor level. These analysis levels are described below along with the specific performance measures associated with each. The scope or extents of the traffic operations model is provided for reference below in **Figure 5.1**.

The traffic operations performance was also quantified in terms of the monetary benefit that may be accrued as a result of the improvements to the corridor. A description of the benefit estimation methodology, including key assumptions, is also included in this section.

Figure 5.1: Traffic Operations Model Network Study Area

5.1.1 Network-Level Measures of Effectiveness

The first and most high-level metric to analyze traffic operations performance are network statistics that represent cumulative impacts to network traffic for the entire study area. Measures of effectiveness are aggregated for high-level comparison. Network measures of effectiveness include the following:

- **Vehicle Hours Traveled (VHT in vehicle-hours):** provides an aggregate measure of the impact of each strategy on the entire freeway segment and adjacent municipal network. This measure is also presented separately for the freeway and municipal network to understand the potential impact of shifting travel patterns due to corridor congestion. A strategy that provides a reduction to the overall vehicle hours traveled is likely an effective strategy. However, it must be cautioned that in the context of this study, an increase in network travel time would not necessarily suggest an ineffective strategy. Improvements to the freeway mainline operations can be accompanied with some disbenefits to the local street network.

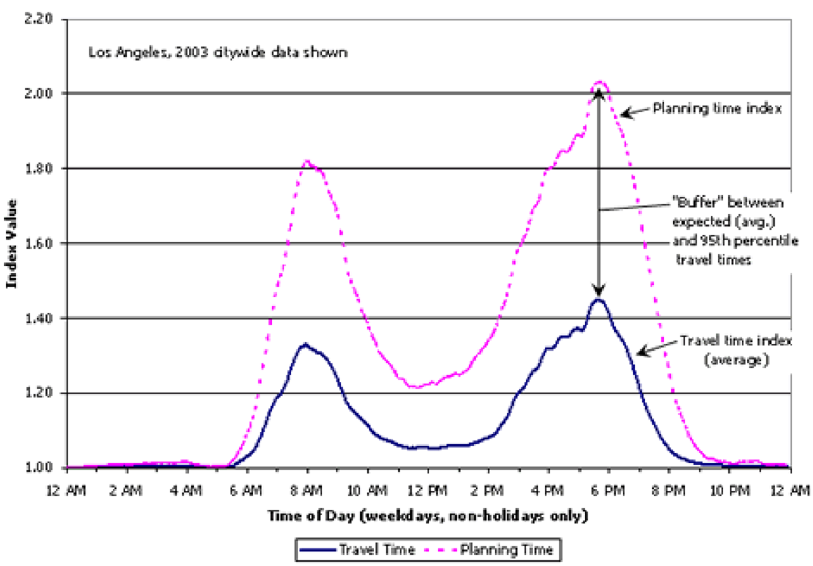
- **Vehicle Miles Traveled (VMT in vehicle-miles):** provides an aggregate measure of the cumulative vehicle travel distance within the study for each peak period. The study area limits contain both the freeway and municipal street network; allowing for redistribution of some trips and variance in route choice. This measure is also presented separately for the freeway and municipal network to understand the potential impact of shifting travel patterns due to corridor congestion. An increase to VMT could suggest diversion to other routes due to congestion.
- **Diversion to Municipal Network:** This measure qualitatively assesses the potential diversion from the freeway to the municipal street network. Volume difference plots were developed to graphically highlight key locations where increases or decreases to traffic volume could be expected.

5.1.2 Corridor-Level Measures of Effectiveness

The second level of traffic operations analysis was conducted at the corridor level. These measures of effectiveness are aimed at understanding freeway mainline traffic operations as well as the performance of the adjoining entrance and exit ramps. Corridor measures of effectiveness include the following:

- **Freeway Speed (Miles per Hour):** Travel speeds were calculated from the detector data (within the traffic operations model) for the entire length of the corridor for the full duration of the peak periods. These values were compared against the posted speed of the freeway facility, or more appropriately compared against the operating speeds associated with the target throughput, to identify areas where the freeway is operating at less than optimal conditions. To estimate the travel speeds both spatially along the corridor and temporally throughout the peak period, data from the virtual detectors was used. The virtual detectors calculate and record the average travel speed of vehicles in each travel lane within each ten-minute interval. An average travel speed can then be calculated for each direction. The resultant information can then be presented in a thematic map where average speed within the ten-minute interval can be plotted by color to illustrate the simulated speeds along the length of the entire facility (x-axis) and peak period (y-axis). The charts generated were analyzed to identify locations and times of increased congestion, which were examined in detail to identify potential causation.
- **Freeway Mainline Throughput (Vehicles per Hour):** Freeway volumes were obtained from the traffic operations model outputs on the various freeway segments between interchanges to provide context with respect to potential increased throughput. The change to throughput was compared between the Baseline scenario and the various strategies. It should be noted that a key objective of any urban freeway is to maximize vehicle throughput at the highest safe travel speed. For many urban freeways, the maximum vehicle throughput is rarely associated with the posted speed of the facility, but rather at a lower speed that maintains traffic flow, while avoiding “stop-and-go” operations.
- **Route Travel Times (Minutes):** Route travel times were extracted for three key sub-routes that cover different spatial locations within the study area. Route travel times provide an easy way to compare the effectiveness of the various strategies. A reduction to travel time generally indicates an improvement to traffic operations. The three key travel time routes are as follows:
  - **Corridor:** End-to-end east-west travel times from approximately IL 394 to I-65. This metric provides a high-level comparison of the directional corridor travel time.
  - **Arterial:** North-south travel times along each arterial crossing the freeway. Travel times were extracted in both directions from generally two intersections north of the freeway to two intersections south of the freeway.
  - **Entrance Ramps:** Travel times measured from the entrance ramp terminal traffic signal to approximately 2-3 miles downstream on the freeway.

- **Travel Time Reliability:** Travel time reliability measures the extent of this unexpected delay and infers the level of consistency or dependability in travel times, as measured from day-to-day and/or across different times of the day. Three key metrics form the quantitative basis to measure reliability and these are presented below:
  - **95th Percentile Travel Time:** Perhaps the simplest measure of travel time reliability is 95th percentile travel times which indicate how worse delay will be on the most congested typical travel days. The 95th percentile travel times are reported in minutes and are easily understood by commuters familiar with their trips. This measure essentially means that given a set of 100 trips, 95 of the 100 trip travel times will fall within this travel time.
  - **Average travel speed:** Another relatively simplistic indicator, this metric involves the measure of the average speed of all vehicles on the freeway during the specified time period. Increases to speed represent improvements to overall traffic operations while decreases indicate worsening of congestion.
  - **Planning time index**: Represents the total travel time that should be planned and includes typical delay as well as unexpected delay. Thus, the planning time index compares near-worst case travel time to a travel time in light or free-flow traffic. For example, a planning time index of 1.60 means that, for a 15 minute trip in light traffic, the total time that should be planned for the trip is 24 minutes (15 minutes × 1.60 = 24 minutes). The planning time index is computed as the 95th percentile travel time divided by the free-flow travel time. See **Figure 5.2** below for a graphical representation of this metric.



Source: FHWA: Travel Time Reliability: Making It There on Time, All the Time Brochure, December 2005

Figure 5.2: Graphical Representation of Planning Time Index

5.1.3 Traffic Operations Assessment Summary

To assist in the assessment process, a qualitative rating system was applied to synthesize the peak-hour analysis outputs for each strategy into a distilled rating system, as shown in **Table 5.1** below. The following six metrics were adopted in the rating scheme:

- **Freeway Speed:** This measure was assessed using the speed contour (heat maps) plots to determine changes to speed in the area of influence.

- **Freeway Mainline Throughput:** This measure was assessed at the closest interchange (upstream or downstream) depending on the configuration.
- **Travel Time Savings:** This measure qualifies the relative improvements to travel time through the corridor.
- **Travel Time Reliability:** This measure assessed the change to unexpected delay and consistency of travel.
- **Municipal Network Traffic Operations:** This measure qualitatively assesses the traffic operations performance of the municipal network adjoining the freeway mainline including entrance ramps and exit ramps and upstream ramp terminal intersections.

Table 5.1: Qualitative Rating System

LEGEND	
↑	Significantly Better
↗	Moderately Better
→	No Change
↘	Moderately Worse
↓	Significantly Worse

5.1.4 Traffic Operations Benefit-Cost Analysis

For each strategy assessed using the traffic operations model, monetized benefit estimation for the purpose of calculating a benefit-cost ratio was undertaken based on the travel time savings achieved by the improvement strategy.

To calculate the traffic operations related benefits, cumulative travel times for the study corridor were first extracted from the traffic operations microsimulation model for both the Existing and Future horizon year scenarios. Results were captured for two peak periods, namely the morning period from 6:00 am to 9:00 am and the afternoon period from 3:00 pm to 6:00 pm.

As noted above, only travel time related benefits were estimated. Other typical traffic operations related benefits, such as those related to vehicle operating cost savings, were not included in order to simplify the analysis process. Therefore, the approach chosen could be considered conservative in that other potential benefits have not been included, however, it is noted that travel time savings typically represent the majority of the traffic operations related benefits.

Input Parameters

The travel time savings also considered occupancy rates, which were obtained from the *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* published by the US DOT in February 2021, as listed below:

- 1.48 persons per vehicle for weekday peak periods; and
- 1.58 persons per vehicle for weekday off-peak periods.

The travel time savings were then converted to monetary values using the auto and truck values of time from the US DOT guidelines stated above, as shown in **Figure 5.3**. The values of time were inflated to 2021 dollars using a rate of 1.06, which reflects the rate of inflation between June 2019 and June 2021 as obtained from the Consumer Price Index (CPI) calculator of the Bureau of Labor Statistics.

Recommended Hourly Values of Travel Time Savings
(2019 U.S. $ per person-hour)

Category	Hourly Value
In-Vehicle Travel[1]	
Personal[2]	$16.50
Business[3]	$27.90
All Purposes[4]	$17.90
Commercial Vehicle Operators[5]	
Truck Drivers	$30.80
Bus Drivers	$31.70
Transit Rail Operators	$50.00
Locomotive Engineers	$49.40

Source: Recommended Monetized Values (US DOT, 2021)
https://www.transportation.gov/sites/dot.gov/files/2021-02/Benefit%20Cost%20Analysis%20Guidance%202021.pdf

Figure 5.3: Value of Travel Time Savings

Expansion Factors

To convert the travel time savings to a yearly monetary value, expansion factors were developed. Traffic volumes for the study corridor were extracted from StreetLight Data obtained for the study. These extracted results were reported hourly over the entire representative weekday and for the peak periods. The average ratio of the morning and afternoon peak periods was compared to the total time period when the TSMO strategies would likely be operational, namely between approximately 6:00 am to 9:00 pm. Based on this comparison, the peak periods-to-daily factor was determined to be 2.45.

To convert the daily factor to an annual factor, Streetlight Data zone activity analyses were performed at eight locations along the study corridor, with data sourced from the entirety of 2019. The analyses were conducted on an average daily basis, producing bi-directional daily volumes. Two averages were generated: one for all days (equivalent to AADT) and one for Tuesday-Thursday only (representative of a typical commuting day). The ratio of the 'All Days' volumes to the 'Tu-Th Only' volumes, multiplied by 365 days, yields a factor for expanding from a typical commuting day to an entire year. This analysis resulted in a daily-to-yearly expansion factor of 381.

Present Value

Benefits were assumed to accrue beginning in 2025 and lasting until 2040 for a cumulative period of 16 years. As two horizon years were evaluated in the traffic operations model (Existing and Future), benefits accrued during the intervening years were assumed to change linearly between the two horizon years.

In addition, the construction duration for each project was assumed to occur over a two-year period starting in 2023, with 50% of the costs incurred during 2023 and 50% during 2024. Construction costs were inflated to construction year dollars using an annual growth rate of 3.7% derived from historical National Highway Construction Index values over an 18-year period between 2003 and 2021.

A discount rate of 4.0% as stated in the Indiana Design Manual (Chapter 50 Economic Analysis) was applied to calculate the present value of the accrued benefits and costs in 2021 dollars. From the present value of the benefits and costs, the net present value (NPV) and benefit-cost ratio (BCR) were determined.

5.1.5 Improvement Strategy Prioritization

There are several summary measures that can be used to compare benefits to costs. The two measures adopted for this study are net present value (NPV) and the benefit-cost ratio (BCR). The first measure, NPV, accounts for all benefits and costs over the life cycle of an improvement strategy. These benefits and costs are discounted to the present (2021), and the costs are subtracted from the benefits to yield a NPV. If benefits exceed costs, the NPV is positive and the project may be considered to be economically justified. The second measure, BCR, is a ratio where the present value of benefits (including negative benefits if any) is placed in the numerator of the ratio and the present value of costs is placed in the denominator. The ratio is usually expressed as a quotient (e.g., $2.2 million/$1.1 million = 2.0). Improvement strategies with the highest BCR yield the greatest ratio of benefits to costs. Based on the BCR, a preliminary prioritization of traffic operations TSMO strategies will be generated with those strategies with the higher BCR ranked higher. It should be noted that this ranking and BCR analysis is based on traffic operations improvements only. There may be other complementary benefits that may be derived from the TSMO strategies and therefore the BCR may be considered conservative and only one indicator.

5.2 TRAFFIC SAFETY TSMO STRATEGIES

Safety benefits related to the traffic safety TSMO strategies were assessed quantitatively through the application of crash modification factors (CMF), which represent the percent reductions in crashes that can be expected after strategy implementation. The three traffic safety TSMO strategies being considered, namely queue warning system, variable speed limits, and dynamic lane control, were assessed where appropriate CMF were available.

A literature review was conducted to identify appropriate CMF from before-and-after studies that used observed crash data to assess changes in safety performance. Various sources of CMF were consulted, including:

- The Crash Modification Factors Clearinghouse[1], a central online repository of CMF funded by the U.S. Department of Transportation Federal Highway Administration (FHWA) and maintained by the University of North Carolina Highway Safety Research Center.
- The ITS Deployment Evaluation Program[2], a central online resource by the USDOT ITS Joint Program Office, which presents summaries on the benefits, costs, deployment levels, and lessons learned for ITS deployment and operations.
- The Joint Transportation Research Program technical report titled “Updating the Crash Modification Factors and Calibrating the IHSDM for Indiana”[3] (Tarko et al., 2018), which updated and expanded the set of CMF applicable to Indiana conditions for various geometric, traffic, pavement, and other road characteristics.

From the literature review, the following CMF were identified to be appropriate for use in the safety benefit assessment:

- **Queue warning system**: Two CMF cited in the Crash Modification Factors Clearinghouse were used, which originate from the Handbook of Road Safety Measures (2004) and are included in the Highway Safety Manual. One factor is 0.84, or a 16% reduction in rear-end injury crashes, and the other factor is 1.16, or a 16% increase in rear-end property damage only (PDO) crashes[4]. These factors are developed from a

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[1] http://www.cmfclearinghouse.org/index.cfm
[2] https://www.itskrs.its.dot.gov/
[3] https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=3184&context=jtrp
[4] http://www.cmfclearinghouse.org/detail.cfm?facid=76

meta-analysis, which could therefore be considered more reliable than factors cited in other studies. The technical report for Indiana does not include a factor for installing a queue warning system.

- **Variable speed limits**: The CMF presented in the technical report for Indiana was used, which is based on a study in Missouri titled "Evaluation of Variable Speed Limits on I-270/I-255 in St. Louis" (Bham et al., 2010). The factor is 0.92, or an 8% reduction in total crashes[5].
- **Dynamic lane control**: Of the evaluation studies available to date, dynamic lane control is often implemented as part of a freeway management system that consists of other TSMO strategies, such as dynamic message signs, variable speed limit, or hard shoulder running. As such, it is not possible to isolate the safety benefits of lane control alone. The technical report for Indiana also does not include a factor for lane control. Therefore, the safety benefits for this TSMO strategy will be assessed qualitatively.

To conduct the quantitative safety benefit assessment for the queue warning system and the variable speed limit strategy, the Road Hazard Analysis Tool (RoadHAT) 4.0 software was used, which is a tool developed to support the Indiana Department of Transportation in traffic safety management. The software uses Safety Performance Functions (SPF) for Indiana that were updated in 2020, and average crash costs that were calculated in 2017 dollars. The Empirical Bayes method employed in the software combines the site crash history and the expected crash frequency of similar facilities in the state using the SPF. The methodology considers the "regression to the mean" effect, as well as change in traffic volume in the analysis period.

The average crash costs included in the RoadHAT tool reference crash costs from the National Safety Council (NSC) and the National Highway Traffic Safety Administration (NHTSA). The NSC cost estimates include wage losses, medical expenses, insurance administrative costs, and property damage. The NHTSA cost estimates include the calculable costs associated with each fatality and injury plus the costs to society. The average crash costs in the RoadHAT tool are calculated based on the number of crashes for each severity occurring on various road facility types in Indiana and weighted by the number of severity crashes. The average crash costs applied in the safety benefit assessment are presented in **Table 5.2** below in 2017 dollars:

Table 5.2: Average Crash Costs in 2017 Dollars (Source: The RoadHAT Software, Version 4.0)

ROAD TYPE	AVERAGE CRASH COSTS (IN 2017 DOLLARS)		
	Fatal and Incapacitating Crashes	Non-Incapacitating and Possible Injury Crashes	Property Damage Only Crashes
Urban Freeway Segment	$2,043,300	$337,700	$36,700
Urban Interchange Freeway Segment	$1,840,000	$321,700	$38,000

The safety benefit assessment was conducted on a segment basis using the segmentation applied in the existing safety performance review, which differentiates segments within the impact zone of an interchange area from segments outside. The following input assumptions were used in the analysis:

- Construction is anticipated to take place in 2023 and 2024, with the systems being in service in 2025. The benefit accrual period was assumed to be from 2025 to 2040 inclusively.
- An annual inflation rate of 2.64% was used to update the average crash costs from 2017 dollars to 2021 dollars, which reflects the rate of inflation observed between September 2017 and September 2021 (the most recent month with available inflation data) as obtained from the Consumer Price Index (CPI) inflation calculator on the U.S. Bureau of Labor Statistics website[6].

[5] https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=3184&context=jtrp
[6] https://www.bls.gov/data/inflation_calculator.htm

- A discount rate of 4% was applied to estimate the present worth of future safety benefits, as per the Indiana Design Manual (Chapter 50 Economic Analysis, updated in April 2016[7]).
- An annual traffic growth rate of 0.76% was assumed for the study corridor, which was calculated based on the increase in daily (24-hour) volumes from 2020 to 2040 in the base case scenarios of the NIRCP travel demand model, assuming the constant growth rate is compounded annually. A segment-specific growth factor was also applied to better reflect segment-based growth.

The number of crashes saved by severity level, as well as present worth benefits, were generated by the software. The RoadHAT methodology was applied to the entire study corridor (approximately 16 miles in length), including the portion in Illinois (approximately three miles in length). Although the RoadHAT software employs Indiana state settings, the RoadHAT approach was applied to the Illinois segments in order to provide a comparable assessment across the entire corridor, given the close proximity of the Illinois portion of the corridor to Indiana.

In terms of cost calculations, the implementation costs presented in **Section 4** were applied. Consistent with the traffic operations benefit-cost analysis, an inflation rate of 3.7% was applied to the capital costs to estimate costs in 2023 and 2024 dollars (the inflation rate was obtained from historical National Highway Construction Index values over an 18-year period between 2003 and 2021). The annual operations and maintenance costs were included in the cost calculations. A discount rate of 4% was applied to calculate the present value of various costs.

5.3 EVENT MANAGEMENT TSMO STRATEGIES

The event management TSMO strategies were assessed both qualitatively and quantitively. The **qualitative assessment** primarily focused on the identification of potential benefits related to reduced delays, enhanced safety, and improved coordination between agencies. Experience gained from previous deployments of similar systems and engineering judgement were applied.

In order to **quantitatively assess** the potential traffic operations related benefits that may be derived from improvements to incident management and response, the traffic operations model will be utilized. An assessment of two key metrics will underpin the analysis; namely, Travel Speed and Vehicle Hours Traveled (VHT). These metrics were previously described in detail in **Section 5.1.1**.

Representative incidents will be simulated within the traffic operations model according to the direction, time of day, and incident lane closure categories. For single-lane closures, a standard one-hour closure will be modeled while multi-lane (2+) closures will be modelled using a two-hour closure duration. These sample incidents provide a simple and conservative way of quantifying incident management and response improvements. Assessment of traffic operations due to incidents will be conducted for both the Existing and Future time horizons and the incremental increase to network travel time will be calculated to establish a baseline for incident-based delay. For each of the incident permutations (direction, time of day, incident type etc.), two incident management and response improvements will be implemented into the traffic operations model. Specifically, improvements to incident detection, verification, and response will be modeled as a five-minute reduction to the incident duration. A second scenario will assume the aforementioned incident management improvements plus operation of a hard shoulder lane segment approximately one-mile upstream and downstream of the incident location.

To provide a more accurate and fulsome representation of the potential annual benefits that may be derived, an assessment and characterization of the existing incidents within the corridor will be undertaken. Incidents

[7] https://www.in.gov/dot/div/contracts/design/Part%203/Chapter%2050%20-%20Economic%20Analysis.pdf

on the corridor are currently catalogued in two different databases: namely the Gateway Traffic Incident Management System (Gateway TIMS) and the INDOT Traffic Incident Management System (INDoT TIMS).

The difference in network travel time between the incident management and response improvement scenarios and the incident baseline scenario will yield the travel time savings. These travel time savings will then be mapped for each incident permutation according to the observed incidents on the corridor generated from the Gateway TIMS and INDOT TIMS databases. The result will be the approximate travel time savings incurred for both improvement scenarios during the 2019 and 2040 horizon years.

The travel time savings were converted to present value benefits using the same methodology to analyze the traffic operations TSMO strategies as detailed in Section 5.1.4. For this analysis, it will also be assumed that the year-over-year change to travel time savings between the Base year and the Future year would be linear in scope and that benefits would only start to accrue in 2025. Benefit to cost ratios will then be generated by dividing the present value benefits by the present value costs associated with the improvement.

5.4 NON TSMO IMPROVEMENT STRATEGIES

The geometric improvements, and specifically the proposed eastbound exit to I-65 south ramp improvements, will be assessed for the Existing and Future horizon years using similar traffic operations related metrics including:

- Vehicle Hours Traveled (VHT)
- Travel speeds
- Travel time
- Level of Service (Highway Capacity Software analysis)
- Travel Time Reliability

In addition, the costs of the proposed works will be included in the analysis such that a benefit to cost ratio (BCR) can be determined along with the net present value (NPV). The benefit to cost analysis will follow the same process as described above for the traffic operations related strategies.

Guide signing will be assessed in qualitative manner considering key indicators such as providing positive guidance, advance warning, and consistent information, all of which are intended to improve traffic safety as well as traffic operations by reducing turbulence and the resulting congestion.

Section 6 – IMPROVEMENT STRATEGY ASSESSMENT

The improvement strategies were assessed using the comprehensive methodology and key assumptions described in the previous section. As noted in the approach, each improvement strategy category was assessed separately from the other strategy categories, with the results of the analysis summarized accordingly in the same manner. The detailed analysis results for each improvement strategy, by category, are attached in **Appendix D**.

Noting the significant congestion that currently occurs at the eastbound exit to I-65 south and the magnitude of the congestion that is forecasted in 2040, it is assumed that the proposed geometric change at this location will be included as an underlying corridor improvement when assessing the other TSMO strategies. This assumption is based on the premise that this issue is located at the end of the study corridor in the eastbound direction, and if left unmitigated, potential benefits resulting from any proposed improvements upstream would be reduced (if not lost) as the unconstrained traffic flow would only move downstream and add to the congestion at this “bottleneck” location.

Given the importance of the above assumption, the assessment results associated with the geometric improvements are presented first and then followed by the assessment results for the Traffic Operations, Traffic Safety, and Event Management related strategies.

6.1 NON TSMO IMPROVEMENT STRATEGIES

The results of the assessment of the non TSMO improvement strategies are summarized below with respect to the following individual strategies:

- Broadway Interchange and I-65 Interchange Modifications
- Signing Enhancements

6.1.1 Broadway Interchange and I-65 Interchange Modifications

Assessment of the effectiveness of the proposed Broadway Interchange and I-65 Interchange geometric modifications (as described in Section 4.4.1) for the Existing and Future horizon years was undertaken using the traffic operations models to conduct a quantitative analysis, in terms of select traffic operations related metrics described in **Section 5.4** and reiterated below:

- Vehicle Hours Traveled (VHT)
- Travel speeds
- Travel time
- Travel Time Reliability

As noted earlier, the traffic operations models for Existing Conditions were calibrated to simulate conditions for the representative weekday AM and PM peak hours in 2019, in order to avoid the impacts associated with the COVID-19 pandemic which affected traffic patterns and volumes in 2020.

Vehicle Hours Traveled (VHT in veh-hr)

The network travel time (VHT) as modeled, is separated into two categories, the I-80/94 mainline and adjoining ramps, and the municipal network. This separation provides a better overview of the effectiveness of the geometric changes with respect to the two broad road classes. The VHT for the AM and PM peak periods are reported in **Table 6.1** and **Table 6.2** below for the Broadway interchange and I-65 interchange modifications relative to the No-Build scenario.

As shown, the Broadway interchange and I-65 interchange modifications provide considerable network travel time savings with a reduction of approximately 200 hours of delay during the AM peak period and 760 hours of delay during the PM peak period in 2040. The travel time savings amount to approximately a 2% reduction in overall network travel time compared to the No-Build scenario.

Table 6.1: AM Peak Period Network-Wide Vehicle Hours Traveled - VHT (Hours)

AREA	CLASS	2019 AM		2040 AM	
		No Build	Broadway I/C and I-65 I/C Modifications	No Build	Broadway I/C and I-65 I/C Modifications
		VHT	Δ (Difference from No Build)	VHT	Δ (Difference from No Build)
I-80/94	Truck	1,880	0 (0%)	2,270	-30 (-1%)
	Auto	8,310	-90 (-1%)	9,540	-90 (-1%)
	Total	10,190	-90 (-1%)	11,810	-120 (-1%)
Municipal	Truck	60	-10 (-17%)	80	0 (0%)
	Auto	6,390	-40 (-1%)	7,200	-90 (-1%)
	Total	6,440	-40 (-1%)	7,270	-80 (-1%)
Total		16,640	-130 (-1%)	19,080	-200 (-1%)

Table 6.2: PM Peak Period Network-Wide Vehicle Hours Traveled - VHT (Hours)

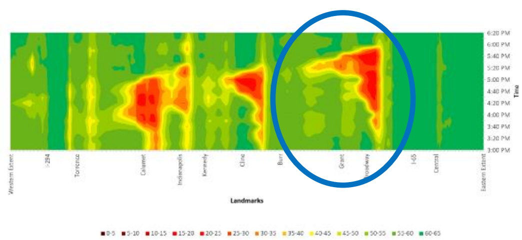
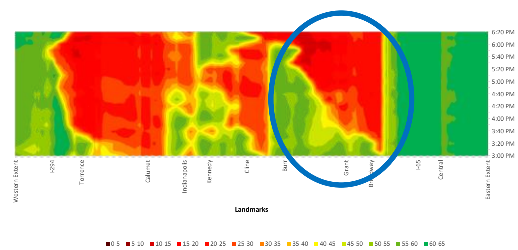
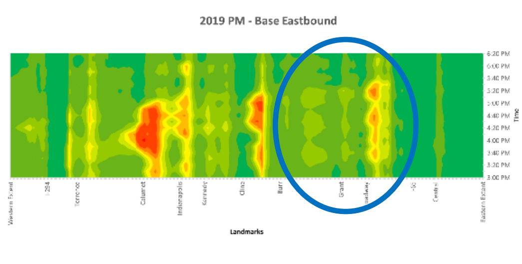
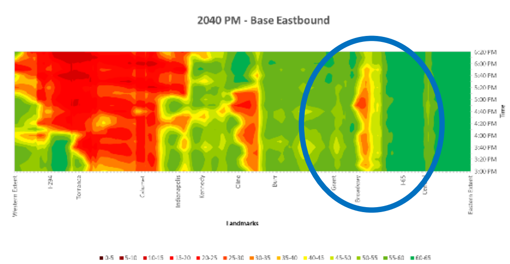
AREA	CLASS	2019 PM		2040 PM	
		No Build	Broadway I/C and I-65 I/C Modifications	No Build	Broadway I/C and I-65 I/C Modifications
		VHT	Δ (Difference from No Build)	VHT	Δ (Difference from No Build)
I-80/94	Truck	2,200	-100 (-5%)	3,490	-200 (-6%)
	Auto	12,700	-290 (-2%)	18,490	-1000 (-5%)
	Total	14,900	-390 (-3%)	21,980	-1200 (-5%)
Municipal	Truck	110	0 (0%)	220	-30 (-14%)
	Auto	11,570	130 (1%)	17,860	470 (3%)
	Total	11,680	130 (1%)	18,080	440 (2%)
Total		26,570	-250 (-1%)	40,060	-760 (-2%)

Freeway Speed (Miles Per Hour)

Freeway speeds were obtained from the traffic operations model outputs and processed into speed contour plots. The color gradient is set from red to green, with a red area signifying congestion and slower speeds whereas a green area indicates minimal congestion and faster speeds. By presenting corridor speeds in this manner, areas with improved traffic operations become apparent by the changes in color. Speed contour plots during the PM peak period in the eastbound direction for the No-Build scenario and with the proposed Broadway interchange and I-65 interchange modifications are shown in **Table 6.3** below. The focal area for the improvement is highlighted with the blue circle.

As shown, eastbound freeway speeds improve significantly in both the Existing and Future horizon years. The temporal and spatial extent of congestion is much more limited with the modifications. Residual congestion does remain near the Broadway interchange; likely due to the traffic from the Broadway interchange eastbound entrance ramp merging with I-80/94 traffic. Vehicles making this maneuver are required to weave through the high-volume eastbound exiting traffic stream to I-65 southbound which causes some turbulence.

Table 6.3: PM Peak Period Eastbound Speed

Scenario	2019 Eastbound	2040 Eastbound
No-Build		
Broadway I/C and I-65 I/C Modifications		

Travel Times (Minutes)

Travel times were obtained from the traffic operations model during peak periods as discussed in **Section 5.1.2.** Travel times for the eastbound direction are presented in terms of distance from the western extent on the X--axis and the cumulative travel time on the Y-axis. The slope of the line is indicative of the magnitude of speed on the corridor. For context, the dashed line indicates the No-build scenario, and the solid line indicates the travel time associated with the Broadway interchange and I-65 interchange modifications.

As shown, travel times are much more stable (with higher implied speeds) with the Broadway interchange and I-65 interchange modifications implemented, particularly in the focus area near the Grant Street interchange and Broadway interchange. Cumulative travel times over the entire length of the study area in the eastbound direction improve by between 5 minutes to 10 minutes.

	(Dashed)	No-Build
	(Solid)	Broadway Interchange & Exit Ramp to I-65 Southbound Modification

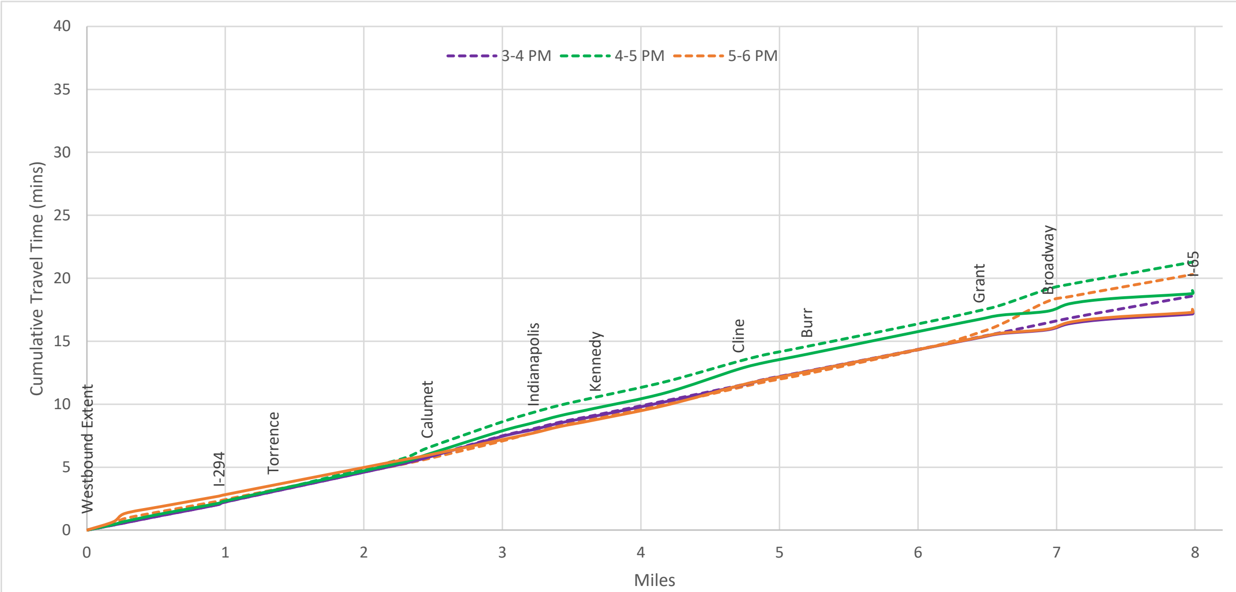


Figure 6.1: 2019 PM Eastbound Corridor Travel Time Plot

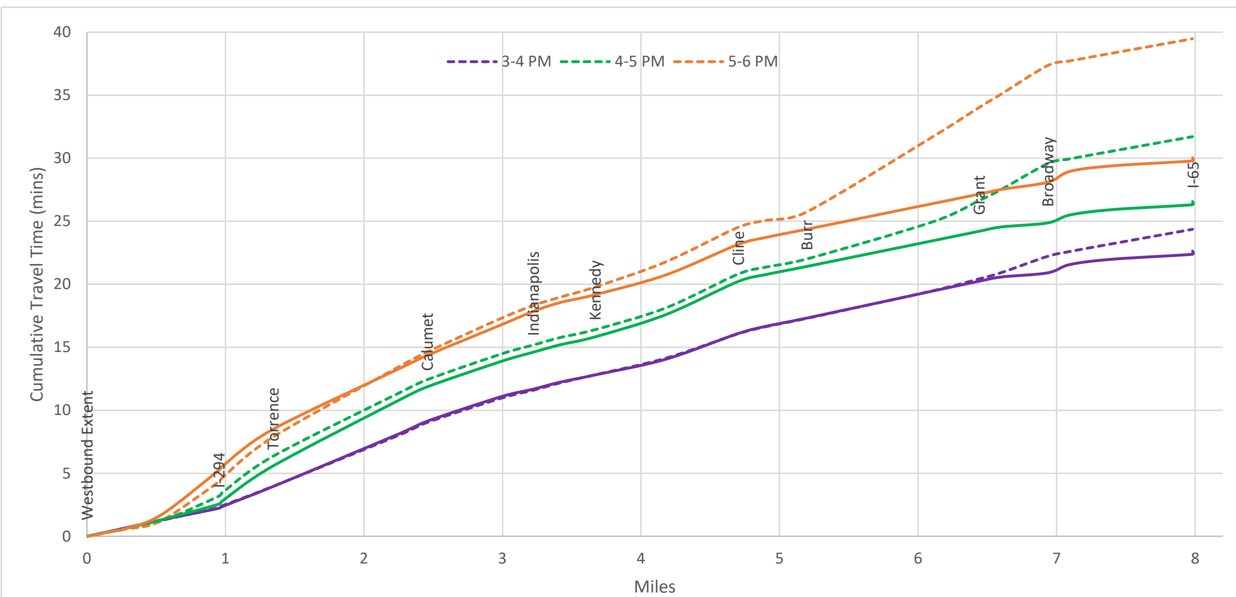


Figure 6.2: 2040 PM Eastbound Corridor Travel Time Plot

Travel Time Reliability

Changes to corridor travel time reliability were assessed using the traffic operations model and are based on the 95th percentile travel time, average travel time, and the planning time index. While there is no individual reliability index, the three metrics can be compared to quantify reliability. The analysis results associated with the Broadway interchange and I-65 interchange modifications were compared to the No-Build scenario for the Existing and Future horizon years and this comparison is presented in **Table 6.4** and **Table 6.5**, respectively.

As shown, the Broadway interchange and I-65 interchange modifications exhibit moderate improvements to average speed with a 3 MPH increase in 2019 and an estimated 5 MPH increase in 2040. The 95% travel times also improve with a 2.4 minute and 4.7 minute improvement expected in 2019 and 2040, respectively. Finally, the planning time index is reduced (indicating more predictable trip durations) for both horizon years.

Table 6.4: 2019 PM Eastbound Travel Time Reliability Metrics

EASTBOUND RELIABILITY METRICS	2019 PM Base - No Build	2019 PM Broadway I/C and I-65 I/C Modifications
Average Speed (MPH)	47.1	50.5
95% Travel Time (mins)	23.9	21.5
Planning Time Index	1.37	1.23

Table 6.5: 2040 PM Eastbound Travel Time Reliability Metrics

EASTBOUND RELIABILITY METRICS	2040 PM Base - No Build	2040 PM Broadway I/C and I-65 I/C Modifications
Average Speed (MPH)	30.4	35.1
95% Travel Time (mins)	36.2	31.5
Planning Time Index	2.07	1.80

Level of Service (Highway Capacity Software Analysis)

The traffic operations model related analysis of the Broadway interchange and I-65 interchange modifications was corroborated using the Highway Capacity Software (HCS) methods and procedures described in the Highway Capacity Manual (HCM). A summary excerpt of the output from HCS analysis comparing the existing and modified configurations is provided below in **Table 6.6**.

Table 6.6: Summary of Eastbound HCS Output

METRIC	EXISTING CONFIGURATION	BROADWAY I/C AND I-65 I/C MODIFICATIONS
Service Flow Rate *(pc/h/ln)*	3630	5300
Service Volume *(veh/hr)*	3420	4980
Resultant LOS	F	F

Note: *Service flow rate corresponding to LOS 'C' is presented as an example*

As shown, the HCS analysis shows that the freeway segment centered on the improvement continues to exhibit a LOS ‘*F*’; however, there is a significant improvement to capacity (service flow rate) by up to 45% over the existing configuration.

Overall, the Broadway interchange and I-65 interchange modifications provide improved lane balance approaching the eastbound exit to I-65 southbound thereby reducing observed congestion, improving travel time, and reliability. By improving the congestion associated with the current exit configuration, greater clarity is permitted when evaluating the traffic operations related benefits stemming from the other proposed TSMO strategies being considered as a means of alleviating upstream bottlenecks. As discussed at the outset of this section, it is assumed that the Broadway interchange and I-65 interchange modifications will be included in the analysis of the other TSMO strategies to allow the benefits of those strategies to be clearly demonstrated.

Detailed Benefit-Cost Analysis Results

This section provides the detailed data used to generate traffic operations related Present Value (PV) benefits, and when combined with the implementation costs, the resulting Benefit-Cost Ratio (BCR) associated with the Broadway interchange and I-65 interchange modifications.

The benefits estimation methodology for the Broadway interchange and I-65 interchange modifications is the same as the methodology used to assess the traffic operations TSMO strategies as described in detail in Section 5.1.4. The resulting present value traffic operations benefits are presented in Table 6.7. It was assumed that the project would be completed by 2025 and would start accruing benefits immediately in 2025 for the next 16 years. All values are presented in 2021 dollars.

Table 6.7: Present Value Benefits from Broadway Interchange and I-65 Interchange Modifications

DESCRIPTION	PV BENEFITS ($ MILLION)
Broadway Interchange and I-65 Interchange Modifications	$148.5

Present Value costs associated with the Broadway interchange and I-65 interchange modifications are highlighted in Table 6.8 below.

Table 6.8: Present Value Costs from Broadway Interchange and I-65 Interchange Modifications

DESCRIPTION	PV COSTS ($ MILLION)
Broadway Interchange and I-65 Interchange Modifications	$4.1

Based on the present value benefits and costs, the BCR was calculated and is shown in Table 6.9 below along with the resulting NPV. The Broadway interchange and I-65 interchange modifications are forecast to achieve a BCR of 36.2 with a NPV of $144.4 million over the 16 year analysis period.

Table 6.9: Benefit-Cost Ratio and NPV from Broadway Interchange and I-65 Interchange Modifications

DESCRIPTION	BCR	NPV ($ MILLION)
Broadway Interchange and I-65 Interchange Modifications	36.2	$144.4

6.1.2 Signing Enhancements

Advance Warning Signs

The current termination of the eastbound left lane at the eastern limits of the study corridor currently experiences congestion during periods of high traffic demand. The presence of slower speeds in the vicinity of the left lane merge suggests that the current warning signs may be inadequate in providing advance warning to drivers approaching the lane ends taper. To improve traffic operations and safety, additional warning / advisory signs are proposed. Key advantages of installing these new signs include:

- Improved advisory messaging to drivers warning of the approaching high speed left lane merge configuration – which is somewhat unconventional and therefore may not meet driver expectations.
- Advanced warning may improve driver actions to potentially merge to the right prior to the lane ends taper and to perform this operation at potentially reduced speeds, appropriate for the operating conditions and roadway configuration.
- The advance warning signs are consistent with INDOT design manual guidance for left lane drops on high speed facilities.

Interchange Sequence Signs

Implementation of interchange sequence signs are proposed as another means to improve traffic operations along the I-80/94 corridor by providing further positive guidance with respect to distance information to the next set of approaching interchange exits. Key advantages of implementing these additional guide signs include:

- Potential for better lane utilization as drivers may remain in the left lanes longer, now knowing the exact distance to their destination exit ramp, rather than continuing to use the right lanes for longer distance due to the lack of sufficient guide signing information. This change in driver behavior may increase overall throughput during free flow conditions if the utilization is more equally distributed or proportional across all lanes.
- Minimizing longer distance travel in the right lane will improve merging operations at each interchange by reducing traffic volumes in the right lane and decreasing lane density.
- Consistent approach used on many urban freeways with closely spaced interchanges.

A disadvantage is the need to mount these signs over the lanes due to the wide cross section / number of lanes and the high percentage of trucks. Median installation is also a possibility as similar signs are located in the northbound and southbound directions of I-69 entering the Indianapolis area.

6.2 TRAFFIC OPERATIONS TSMO STRATEGIES

This section documents the resultant traffic operations performance of the seven traffic operations TSMO strategies and strategy combinations, as highlighted in **Table 6.10**, by applying the methodology described in **Section 5.1**. For simplicity, the analysis results presented in this section represent only the Future Base Case scenario.

Subsequent to the analysis of the strategies with respect to the individual traffic operations metrics, a summary of the overall performance of each Traffic Operations TSMO strategy and strategy combination is provided, followed by a benefits analysis including the projected BCR and NPV.

Table 6.10: Traffic Operations TSMO Strategies and Strategy Combinations

STRATEGY COMBINATION	DESCRIPTION
	Ramp Metering
	Dynamic Shoulder Lanes
	Variable Speed Limit
SC1	Dynamic Shoulder Lanes + Ramp Metering
SC2	Dynamic Shoulder Lanes + Variable Speed Limits
SC3	Ramp Metering + Variable Speed Limits
SC4	Dynamic Shoulder Lanes + Ramp Metering + Variable Speed Limits

6.2.1 Traffic Operations TSMO Assessment

The proposed traffic operations TSMO strategies and strategy combinations were analyzed using the micro-simulation model for the AM and PM peak periods and applying the traffic operations performance metrics identified in **Section 5.1**, including throughput, speed, travel time, and reliability amongst others. Comparison to the Future Base Case scenario traffic operations performance is provided for each performance metric. The full set of results including traffic operations performance for the Existing horizon year are provided in **Appendix D.** The assessment is segmented into two discrete analysis levels, namely:

- Network Level, and
- Corridor Level.

Network-Level Results

Network statistics provide a simple comparison of the overall traffic operations performance of each strategy and strategy combination relative to the Baseline scenario for the entire study area network, inclusive of the I-80/94 corridor and all adjoining ramps and municipal roadways. A comparison of the 2040 Future Baseline scenario and applicable traffic operations TSMO strategies and strategy combinations is presented in this section. The legend below defines the symbols used in the assessment result tables:

Legend:	**Abs.**	Absolute value (unit per table type)
	Δ	Difference between the Base and each scenario (with a change from the Base in the undesirable direction shown in red)

Vehicle Hours Traveled (VHT in Vehicle-Hours)

Results: The network travel time (VHT) as modeled, is separated into two categories, the I-80/94 mainline and adjoining ramps, and the municipal network. This separation provides a more refined understanding of the effectiveness of each TSMO strategy combination with respect to the two broad road classes. The VHT for the AM and PM peak periods are reported in **Table 6.11** and **Table 6.12** below for all traffic operations TSMO strategies and strategy combinations relative to the Future Baseline scenario. In the tables, Red text is included to identify increases in travel time as compared to the Future Baseline scenario, and thus represent an undesirable result.

Table 6.11: 2040 AM Vehicle Hours Traveled (Hours)

AREA	CLASS	-				SC1	SC2	SC3	SC4
		Base	RM	DSL	VSL	DSL RM	DSL VSL	RM VSL	DSL RM VSL
		Abs.	Δ (%)	Δ (%)	Δ (%)	Δ (%)	Δ (%)	Δ (%)	Δ (%)
I-80/94	Truck	2,240	0 (0%)	76 (3%)	0 (0%)	68 (3%)	76 (3%)	0 (0%)	70 (3%)
	Auto	9,450	40 (0%)	487 (5%)	-20 (0%)	464 (5%)	496 (5%)	20 (0%)	473 (5%)
	Total	11,690	40 (0%)	563 (5%)	-20 (0%)	533 (5%)	572 (5%)	20 (0%)	543 (5%)
Municipal	Truck	80	0 (0%)	-1 (-1%)	0 (0%)	-2 (-3%)	-1 (-1%)	0 (0%)	-2 (-3%)
	Auto	7,110	30 (0%)	212 (3%)	-20 (0%)	204 (3%)	194 (3%)	0 (0%)	202 (3%)
	Total	7,190	30 (0%)	211 (3%)	-20 (0%)	201 (3%)	193 (3%)	0 (0%)	200 (3%)
Total		**18880**	**70 (0%)**	**770 (4%)**	**-40 (0%)**	**730 (4%)**	**760 (4%)**	**20 (0%)**	**740 (4%)**

Table 6.12: 2040 PM Vehicle Hours Traveled (Hours)

AREA	CLASS	-				SC1	SC2	SC3	SC4
		Base	RM	DSL	VSL	DSL RM	DSL VSL	RM VSL	DSL RM VSL
		Abs.	Δ (%)	Δ (%)	Δ (%)	Δ (%)	Δ (%)	Δ (%)	Δ (%)
I-80/94	Truck	3,290	-210 (-6%)	-373 (-11%)	-90 (-3%)	-415 (-13%)	-408 (-12%)	-110 (-3%)	-405 (-12%)
	Auto	17,490	-1100 (-6%)	-1650 (-9%)	-520 (-3%)	-1886 (-11%)	-1807 (-10%)	-580 (-3%)	-1814 (-10%)
	Total	20,780	-1310 (-6%)	-2023 (-10%)	-600 (-3%)	-2302 (-11%)	-2216 (-11%)	-690 (-3%)	-2219 (-11%)
Municipal	Truck	190	0 (0%)	+11 (6%)	-20 (-11%)	2 (1%)	4 (2%)	-10 (-5%)	-4 (-2%)
	Auto	18,330	+840 (5%)	-1081 (-6%)	-1960 (-11%)	-1093 (-6%)	-1254 (-7%)	-1120 (-6%)	-1115 (-6%)
	Total	18,520	+840 (5%)	-1070 (-6%)	-1980 (-11%)	-1092 (-6%)	-1250 (-7%)	-1120 (-6%)	-1119 (-6%)
Total		39300	**-470 (-1%)**	**-3090 (-8%)**	**-2580 (-7%)**	**-3390 (-9%)**	**-3470 (-9%)**	**-1810 (-5%)**	**-3340 (-8%)**

Observations: Based upon the comparison of network travel time results, this metric can provide insight on whether there is an improvement to congestion for the traffic operations TSMO strategies and strategy combinations relative to the Future Baseline scenario:

- During the 2040 AM peak period, the Ramp Metering and Variable Speed Limits strategies provide neutral improvements to network travel time. Interestingly, the Dynamic Shoulder Lanes strategy and strategy combinations that include the dynamic shoulder lane (SC1, SC2, and SC4) increase the overall network travel time. This is attributed to the fact that the increased capacity afforded by the dynamic shoulder lanes draws trips to I-80/94 without improving upon the already stable and non-congested traffic operations performance of the Base scenario during the AM peak period.
- During the 2040 PM peak period, the Dynamic Shoulder Lanes strategy and strategy combinations with dynamic shoulder lanes (SC1, SC2, and SC4) experience the largest reductions to VHT. Despite the attraction of trips to the corridor due to increased capacity, the alleviation of pre-existing congestion through application of the shoulder lane more than compensates for the additional trips in the network.
- Examining impacts to I-80/94 specifically, the Ramp Metering strategy exhibits significant travel time savings while the Variable Speed Limits strategy only provides a minor improvement. The municipal network experiences an increase to VHT with the Ramp Metering strategy in place, likely due to the ramp meters penalizing short interchange-to-interchange trips from using the freeway and instead moving these trips to the local street network.
- The implementation of the Variable Speed Limits strategy provides benefits to the 2040 PM peak period local street network. Based on observations, the reduction to VHT can be attributed to improvements to the Torrence Avenue and IL 394 interchange entrance / exit ramps and adjoining arterial intersections which corresponds to the western-most start/end points of the proposed variable speed limit system.

Vehicle Miles Traveled (VMT in Vehicle Miles)

Results: The network travel distance (VMT) as modeled, is also separated into two categories: the I-80/94 mainline and adjoining ramps, and the municipal network. The VMT for the 2040 AM and PM peak periods are reported in **Table 6.13** and **Table 6.14** below for all traffic operations TSMO strategies and strategy combinations relative to the Future Baseline scenario.

Table 6.13: 2040 AM Vehicle Miles Traveled (Thousand Miles)

AREA	CLASS	-				SC1	SC2	SC3	SC4
		Base	RM	DSL	VSL	DSL RM	DSL VSL	RM VSL	DSL RM VSL
		Abs.	Δ (%)	Δ (%)	Δ (%)	Δ (%)	Δ (%)	Δ (%)	Δ (%)
I-80/94	Truck	207	-1 (0%)	+5 (2%)	-1 (0%)	+4 (2%)	+4 (2%)	-1 (0%)	+4 (2%)
	Auto	876	-4 (0%)	+29 (3%)	-3 (0%)	+26 (3%)	+29 (3%)	-4 (0%)	+26 (3%)
	Total	1,083	-4 (0%)	+33 (3%)	-4 (0%)	+30 (3%)	+33 (3%)	-5 (0%)	+30 (3%)
Municipal	Truck	3	0 (-1%)	0 (-4%)	0 (-1%)	0 (-6%)	0 (-5%)	0 (-2%)	0 (-7%)
	Auto	275	0 (0%)	+5 (2%)	-1 (0%)	+5 (2%)	+5 (2%)	0 (0%)	+5 (2%)
	Total	281	0 (0%)	+5 (2%)	-1 (0%)	+5 (2%)	+5 (2%)	0 (0%)	+5 (2%)
Total		1,364	-4 (0%)	+38 (3%)	-4 (0%)	+35 (3%)	+38 (3%)	-5 (0%)	+35 (3%)

Table 6.14: 2040 PM Vehicle Miles Traveled (Thousand Miles)

AREA	CLASS	-				SC1	SC2	SC3	SC4
		Base	RM	DSL	VSL	DSL RM	DSL VSL	RM VSL	DSL RM VSL
		Abs.	Δ (%)	Δ (%)	Δ (%)	Δ (%)	Δ (%)	Δ (%)	Δ (%)
I-80/94	Truck	204	6 (3%)	14 (7%)	2 (1%)	14 (7%)	14 (7%)	4 (2%)	14 (7%)
	Auto	1,096	3 (0%)	76 (7%)	0 (0%)	75 (7%)	80 (7%)	-5 (0%)	76 (7%)
	Total	1,301	9 (1%)	90 (7%)	1 (0%)	89 (7%)	94 (7%)	-1 (0%)	89 (7%)
Municipal	Truck	5	0 (1%)	0 (5%)	0 (-2%)	0 (2%)	0 (5%)	0 (1%)	0 (0%)
	Auto	442	2 (0%)	2 (0%)	0 (0%)	6 (1%)	2 (0%)	2 (0%)	4 (1%)
	Total	449	2 (1%)	2 (0%)	0 (0%)	6 (1%)	2 (1%)	2 (0%)	4 (1%)
Total		1,364	11 (1%)	92 (5%)	1 (0%)	95 (5%)	96 (5%)	1 (0%)	94 (5%)

Observations: Based upon the comparison of network travel distance results, this metric can provide insight on whether vehicles are traveling along shorter or longer routes in the traffic operations TSMO strategies and strategy combinations relative to the Future Baseline scenario:

- During the 2040 AM peak period, only three of the seven traffic operations TSMO scenarios experience a lower VMT in comparison with the Future Baseline scenario. The decrease is marginal, at less than one percent, and only applies to strategies or strategy combinations without dynamic shoulder lanes (the Ramp Metering strategy, the Variable Speed Limits strategy, and the Ramp Metering and Variable Speed Limits strategy combination). This observation indicates that travel patterns and trip routes remain similar to the Future Baseline scenario.
- The Dynamic Shoulder Lanes strategy and strategy combinations that incorporate dynamic shoulder lanes during the 2040 AM peak period experience a three percent increase in VMT. Most of the increase is attributed to the I-80/94 corridor, at 30,000 additional miles compared to only 5,000 additional miles associated with the municipal network. While the additional travel demand induced by the use of the shoulder lane may partly explain this phenomenon, it is likely that the additional capacity has slightly affected route choices. With dynamic shoulder lanes in place, the attraction of the I-80/94 corridor is slightly higher, leading to increased corridor VMT. The additional miles traveled on the municipal network is likely caused by increased traffic demands and by vehicles taking a slightly longer route to access the I-80/94 corridor instead of taking a direct path through local streets to their destinations.
- During the 2040 PM peak period, traffic operations TSMO strategies and strategy combinations without dynamic shoulder lanes experience a lower magnitude of change in VMT. The Ramp Metering strategy experiences a one percent increase in VMT, mostly originating from the I-80/94 corridor. This result likely indicates more vehicles are being processed on the I-80/94 corridor as corridor speeds have increased due to ramp metering. The Variable Speed Limits strategy, as well as the Ramp Metering and Variable Speed Limits strategy combination (SC3), both experience less than one percent increases in VMT.
- The largest increase in VMT during the PM peak period is associated with the Dynamic Shoulder Lanes strategy and traffic operations TSMO strategy combinations that incorporate dynamic shoulder lanes. On average, the total increase is five percent. Most of the increase is attributed to the I-80/94 corridor, at

approximately 90,000 additional VMT compared to 3,500 additional VMT associated to the municipal network. Since the PM peak in the Future Baseline scenario is highly congested, the additional capacity from the shoulder lanes allows increased throughput on the corridor. This increased throughput equates to greater VMT as more vehicles are processed. Similar to the 2040 AM period, the additional VMT on the municipal network is likely caused by increased traffic demands and route choices. Vehicles are likely taking a slightly longer route to use the I-80/94 corridor instead of taking a direct path through local streets to their destinations.

Diversion to Municipal Network: Corridor Level

Results: Diversion to the municipal network is a qualitative metric that provides some explanation to the changes in VHT and VMT as presented above. By comparing traffic volumes from the traffic operations TSMO strategies and strategy combinations and Future Baseline scenario, traffic pattern changes may be detected to provide reasoning for changes in VHT and VMT. The strategies and strategy combinations with potential traffic pattern changes are presented by volume difference plots in **Appendix D**.

Observations Based upon the volume difference plots, the following observations can be made regarding diversions to the municipal network within certain scenarios:

- Due to minimal congestion in the 2040 AM peak period, travel patterns and route choices remain similar to the Future Baseline scenario. As a result, no notable differences are observed for six of the seven traffic operations TSMO strategy scenarios.
- During the 2040 PM peak period, changes in route choice become more apparent due to increased travel demand on the corridor.
- In the Ramp Metering strategy, approximately 300 fewer vehicles are observed near the Calumet Avenue eastbound entrance-ramp during the peak hour. Since this entrance ramp is metered significantly to improve corridor operations, it is likely that vehicles are choosing an alternate route. A potential entrance point may be Torrence Avenue, since the northbound segment from Ridge Road experiences a 100 to 200 vehicle per hour increase. Overall, an increase to the local street network volume was observed with the application of the ramp meters; although the magnitude of change was only moderate and ultimately the ramp meter operations could be altered to increase or decrease the impact to the local street network.
- In the Dynamic Shoulder Lanes strategy, exit ramp volumes to southbound Indianapolis Boulevard, Kennedy Avenue and southbound Burr Street experience slight increases of 100 to 200 vehicles per hour. This increase likely signifies that the improved corridor operations attract trips that would otherwise be made through the local street network.
- There is no significant change in route choices during the 2040 PM peak for the Variable Speed Limits strategy.
- The combination of ramp metering and variable speed limits in SC3 presents a similar pattern to the Ramp Metering strategy. Ramp traffic near Calumet Avenue, Indianapolis Boulevard, and Kennedy Avenue experience slightly reduced volumes likely due to ramp metering.
- The remaining 2040 PM peak traffic operations TSMO strategy combinations are SC1, SC2, and SC4, which all utilize dynamic shoulder lanes. Diversions in traffic routing are similar for these three strategy combinations. The southbound arterials along Indianapolis Boulevard, Kennedy Avenue, and Burr Street all experience a slight increase in traffic volumes. Specific to SC1 and SC4, there is also a reduction of 100 to 200 vehicles per hour in the southbound direction along Broadway.

Corridor-Level Results

Corridor-level measures of effectiveness are aimed at understanding the I-80/94 mainline traffic operations as well as the performance of the adjoining entrance and exit ramps.

Corridor performance metrics include:

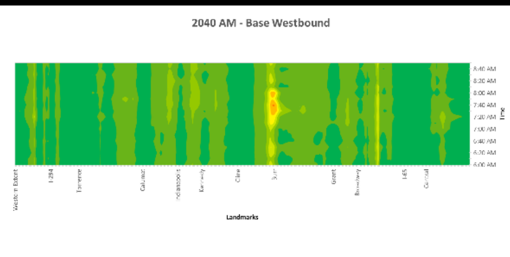
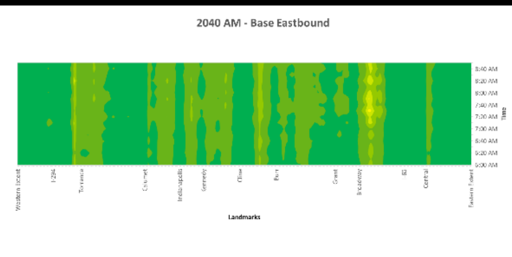
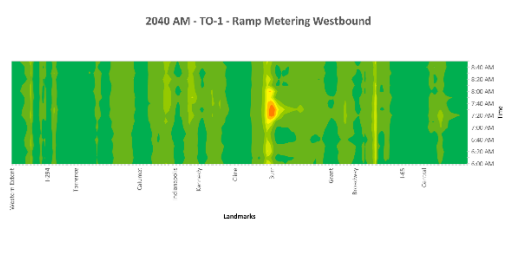
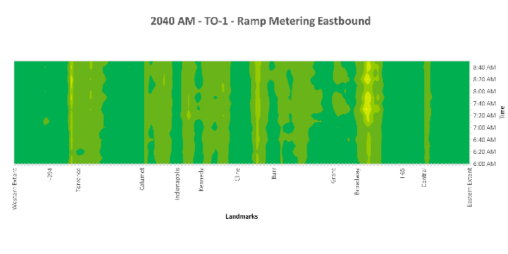
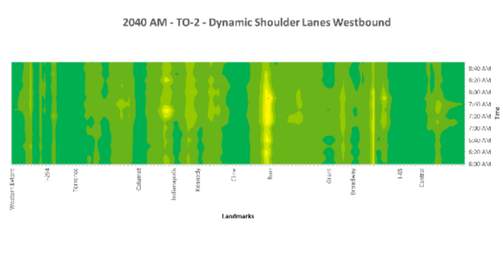
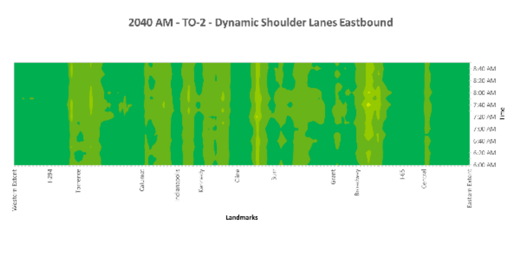
- Freeway Speed (Miles per hour)
- Freeway Mainline Throughput (Vehicles per hour)
- Travel Times (Minutes)
- Travel Time Reliability.

Freeway Speed (Miles per Hour)

Results: Freeway speeds were obtained from the traffic operations model outputs and processed into speed contour plots. The color gradient is set from red to green, with a red area signifying congestion and slower speeds whereas a green area indicates minimal congestion and faster speeds. By presenting corridor speeds in this manner, areas with improved traffic operations become apparent by the changes in color. Speed contour plots for the Future Baseline scenario and key traffic operations TSMO strategies are shown in **Table 6.15** to **Table 6.16** below along with a legend presented in **Figure 6.3** describing the color scheme with respect to the associated speeds. Speed contour plots for the Existing traffic operations TSMO strategies and strategy combinations are found in **Appendix D**.

Figure 6.3: Legend for Speed-Heat Map Colors (MPH)

Table 6.15: 2040 AM Speed Heat Maps

Scenario	Westbound	Eastbound
2040 AM - Base		
2040 AM Ramp Metering		
2040 AM Dynamic Shoulder Lanes		

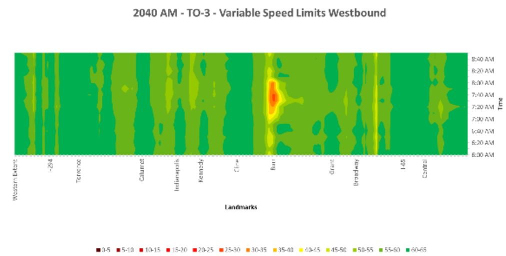
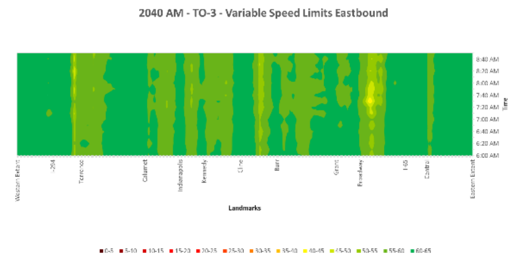
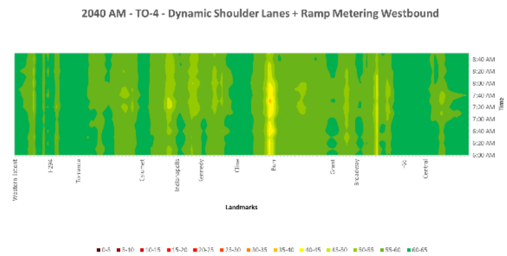
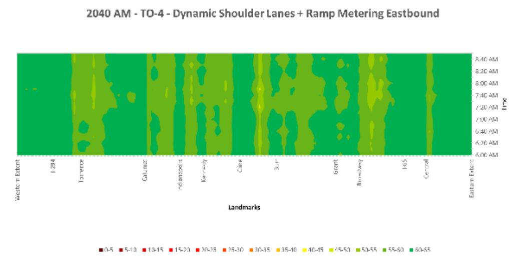
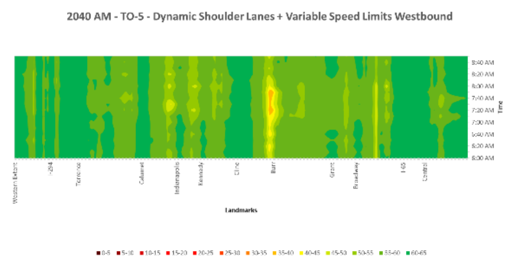
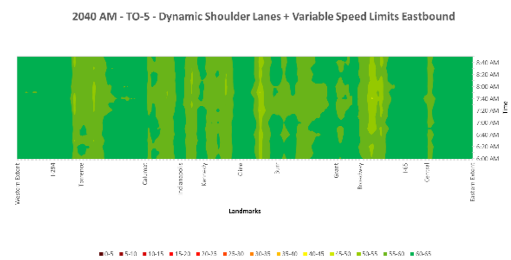
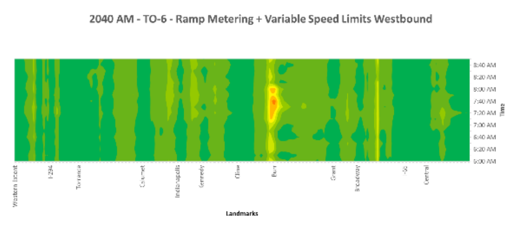
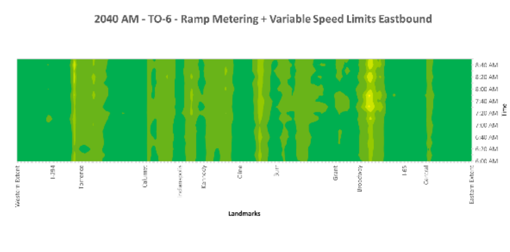
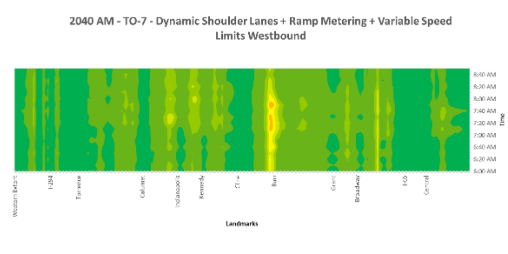
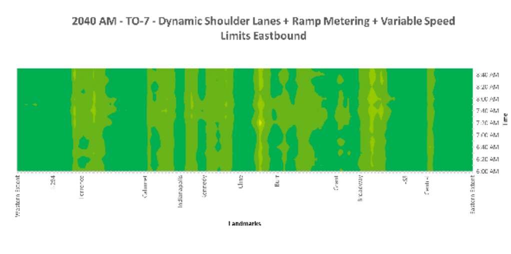
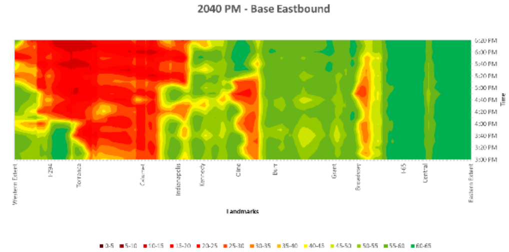
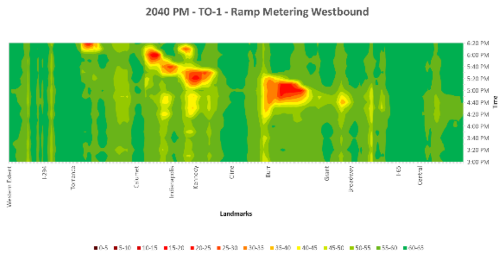
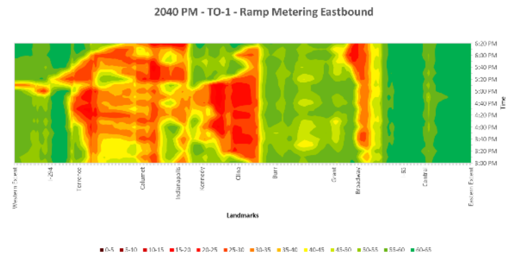
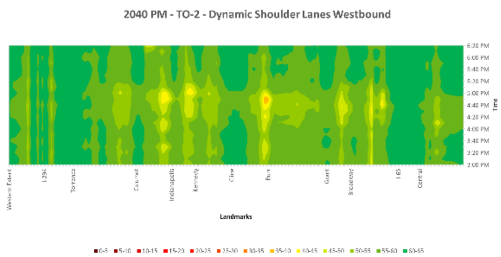
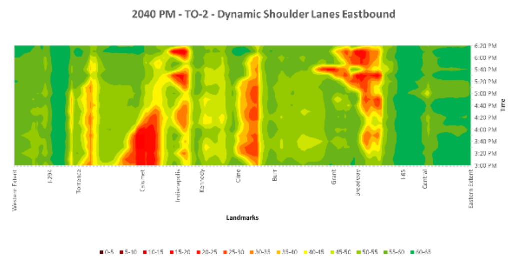
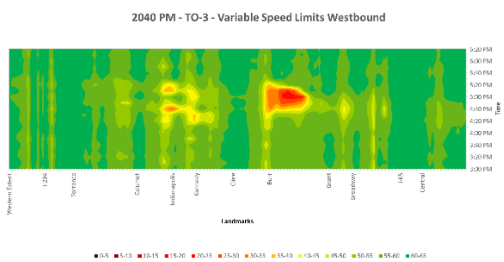
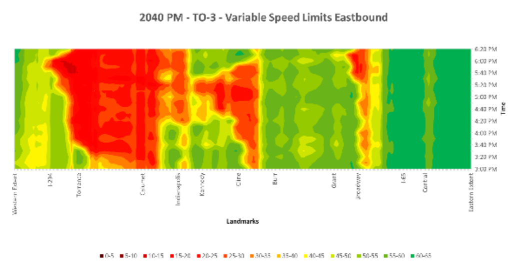
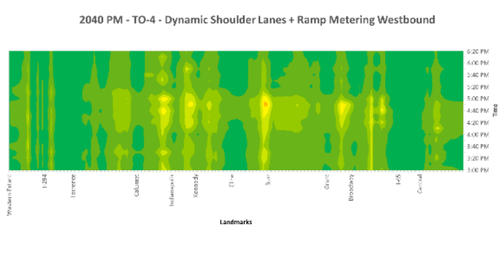
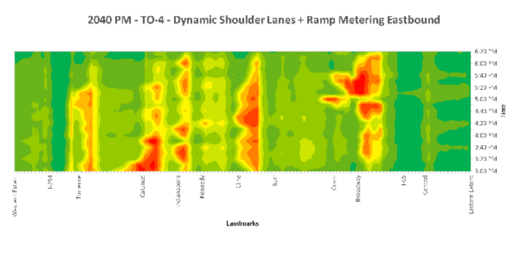
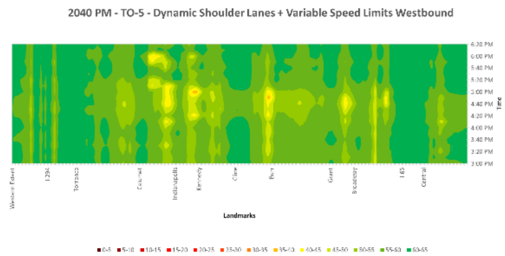
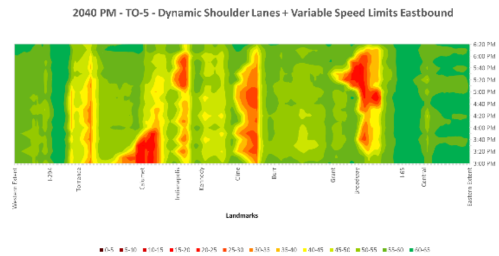
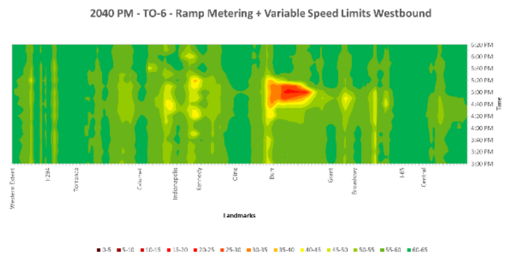
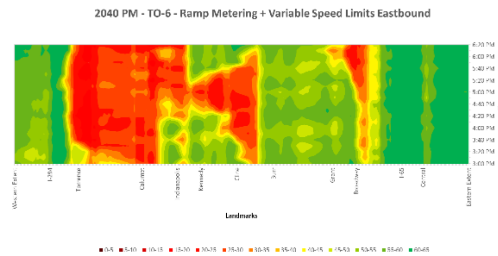
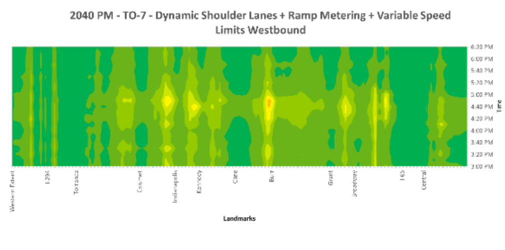
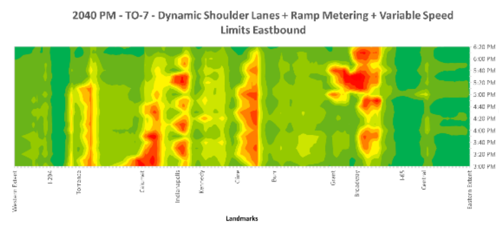
Scenario	Westbound	Eastbound
2040 AM Variable Speed Limits		
2040 AM SC1 Dynamic Shoulder Lanes + Ramp Metering		
2040 AM SC2 Dynamic Shoulder Lanes + Variable Speed Limits		
2040 AM SC3 Ramp Metering + Variable Speed Limits		
2040 AM SC4 Dynamic Shoulder Lanes + Ramp Metering + Variable Speed Limits		

Table 6.16: 2040 PM Speed Heat Maps

Scenario	Westbound	Eastbound
2040 PM - Base		
2040 PM Ramp Metering		
2040 PM Dynamic Shoulder Lanes		
2040 PM Variable Speed Limits		
2040 PM SC1 Dynamic Shoulder Lanes + Ramp Metering		

Scenario	Westbound	Eastbound
2040 PM SC2 Dynamic Shoulder Lanes + Variable Speed Limits		
2040 PM SC3 Ramp Metering + Variable Speed Limits		
2040 PM SC4 Dynamic Shoulder Lanes + Ramp Metering + Variable Speed Limits		

Observations: Based upon the comparison of speed contour plots, the following observations can be made regarding the average speeds and congestion in the traffic operations TSMO strategies and strategy combinations relative to the Future Baseline scenario:

- Traffic operations TSMO strategies and strategy combinations during the 2040 AM period generally provide marginal improvements to the corridor as there is minimal congestion in the Future Baseline scenario. However, it is noted that the Dynamic Shoulder Lanes strategy and strategy combinations with dynamic shoulder lanes provide the greatest improvement to the westbound congestion near Burr Street.
- During the 2040 PM period, benefits of implementing traffic operations TSMO strategies and strategy combinations are seen across all scenarios, ranging from marginal to significant improvements.
- In the Ramp Metering strategy, the Future Baseline congestion between Torrence Avenue and Kennedy Avenue is significantly reduced due to a slower release of entrance ramp vehicles leading to increased corridor speeds. However, as corridor operations are improved, the downstream bottlenecks at Cline Avenue and Broadway worsen.
- The Dynamic Shoulder Lanes strategy provides the greatest improvement within the three individual strategy scenarios. The additional capacity enables higher speeds and less congestion.
- In the Variable Speed Limits strategy, variable speed limits were applied to the start of the Future Baseline congestion, located near Torrence Avenue in the eastbound direction, and Burr Avenue in the westbound direction. In the eastbound direction, the Future Baseline congestion west of Torrence Avenue is minimized while downstream locations remain similar. There is minimal change to the westbound congestion.

- In the strategy combinations SC1 (Dynamic Shoulder Lanes + Ramp Metering) and SC2 (Dynamic Shoulder Lanes + Variable Speed Limits), both provide significant improvements to corridor speeds and congestion. The dynamic shoulder lane is likely a large contributor to the improved corridor.
- The combination of ramp metering and variable speed limits in the strategy combination SC3 results in marginal improvements to corridor speeds and congestion. In this strategy combination, the Future Baseline congestion west of Torrence Avenue is minimized. Upon a closer comparison of the strategy combination SC3 (Ramp Metering + Variable Speed Limits) and the Variable Speed Limits strategy, the vehicle speeds between Torrence Avenue and Calumet Avenue are marginally higher. The interface between ramp metering and variable speed limits seems to yield limited synergies to traffic operations on the corridor.
- From a corridor speed and congestion standpoint, the strategy combination SC4 which utilizes all three traffic operations TSMO strategies, provides improvements on par with strategy combinations SC1 and SC2. Similarly, it is likely that the dynamic shoulder lane is a large contributor to the improved traffic operations.

Freeway Mainline Throughput (Vehicles per Hour)

Freeway throughput volumes were obtained from the traffic operations model outputs for various freeway segments at interchanges to provide context on the number of vehicles being processed. The change to throughputs for the AM and PM peak hours, are compared between the Future Base scenario and the traffic operations TSMO strategies and strategy combinations in **Table 6.17** and **Table 6.18** below.

Table 6.17: 2040 AM Freeway Throughput (Vehicles per Hour)

		-				SC1	SC2	SC3	SC4
		Base	**RM**	**DSL**	**VSL**	**DSL RM**	**DSL VSL**	**RM VSL**	**DSL RM VSL**
		Volume (vph)	**Δ**	**Δ | Volume DSL**	**Δ**	**Δ | Volume DSL**	**Δ | Volume DSL**	**Δ**	**Δ | Volume DSL**
Mainline Eastbound	I-94	4,800	+0	-70 | –	+0	-70 | –	-70 | –	+0	-70 | –
	Torrence	5,000	+10	-150 | 20	+10	-150 | 10	-160 | 20	+10	-140 | 10
	Calumet	4,650	+0	+20 | 20	-10	+20 | 30	+30 | 30	-10	+30 | 10
	Indianapolis	5,000	0	+20 | 80	+0	0 | 60	+20 | 60	-10	+10 | 40
	Kennedy	5,250	-10	+40 | 90	0	+30 | 110	+20 | 80	-20	+0 | 100
	Cline	4,650	0	+60 | 70	+0	+70 | 50	+60 | 60	+0	+60 | 60
	Burr	5,300	+0	+80 | 90	+10	+70 | 70	+80 | 70	+0	+70 | 60
	Grant	5,300	-20	-40 | 170	-20	-30 | 180	-30 | 150	-30	-30 | 150
	Broadway	5,200	+10	-90 | 220	0	-100 | 200	-80 | 200	+20	-90 | 180
	I-65	2,800	0	+140 | –	+0	-20 | –	+150 | –	0	-20 | –
Mainline Westbound	I-94	4,450	+0	+230 | –	-30	+210 | –	+220 | –	-10	+210 | –
	Torrence	3,950	+0	+240 | –	-20	+230 | –	+240 | –	-10	+220 | –
	Calumet	4,700	+0	+450 | 110	-10	+440 | 150	+430 | 110	-20	+420 | 130
	Indianapolis	5,200	+10	+490 | 350	-40	+450 | 340	+490 | 300	-30	+440 | 280
	Kennedy	5,400	-10	+460 | 290	-40	+420 | 310	+470 | 330	-20	+400 | 300
	Cline	4,750	+10	+410 | 100	-10	+400 | 90	+410 | 110	-10	+390 | 90
	Burr	5,800	+10	+400 | 790	-20	+390 | 770	+410 | 880	-20	+360 | 840
	Grant	5,650	+20	+320 | 190	+10	+310 | 150	+330 | 190	-10	+300 | 170
	Broadway	5,300	+10	+320 | 160	+10	+300 | 130	+320 | 160	+20	+310 | 150
	I-65	2,900	0	+190 | –	0	+190 | –	+190 | –	+0	+190 | –

Table 6.18: 2040 PM Freeway Throughput (Vehicles per Hour)

		-				SC1	SC2	SC3	SC4
		Base	**RM**	**DSL**	**VSL**	**DSL RM**	**DSL VSL**	**RM VSL**	**DSL RM VSL**
		Volume (vph)	**Δ**	**Δ | Volume DSL**	**Δ**	**Δ | Volume DSL**	**Δ | Volume DSL**	**Δ**	**Δ | Volume DSL**
Mainline Eastbound	I-94	5,300	-50	+220 | --	+10	+220 | --	+220 | --	+20	+200 | --
	Torrence	5,950	+20	+680 | 360	-300	+630 | 320	+610 | 350	-300	+660 | 360
	Calumet	5,650	+320	+1280 | 1250	+90	+1130 | 910	+1160 | 930	+200	+1160 | 1000
	Indianapolis	6,050	+170	+1560 | 1530	+70	+1390 | 1480	+1380 | 1460	+100	+1430 | 1550
	Kennedy	6,300	+0	+1350 | 1470	+110	+1260 | 1420	+1210 | 1390	-70	+1250 | 1400
	Cline	5,800	-30	+1050 | 1470	+40	+970 | 1460	+980 | 1510	-50	+910 | 1410
	Burr	6,400	+80	+910 | 1100	+20	+850 | 1060	+940 | 1110	-40	+780 | 1010
	Grant	6,350	+120	+790 | 1210	+20	+600 | 1130	+830 | 1170	-10	+550 | 1080
	Broadway	6,200	+420	+750 | 1280	+90	+610 | 1280	+820 | 1310	+30	+520 | 1170
	I-65	3,000	+150	+490 | --	+30	+390 | --	+470 | --	+40	+490 | --
Mainline Westbound	I-94	4,800	-60	+180 | --	+20	+200 | --	+220 | --	+30	+200 | --
	Torrence	4,100	-90	+220 | --	+20	+240 | --	+270 | --	+20	+240 | --
	Calumet	5,550	-60	+150 | 300	-10	+190 | 350	+260 | 350	-30	+160 | 340
	Indianapolis	5,900	+80	+430 | 680	+140	+400 | 670	+490 | 720	+70	+390 | 650
	Kennedy	6,100	+40	+360 | 670	+0	+450 | 730	+480 | 740	-20	+420 | 710
	Cline	5,400	+0	+490 | 320	+0	+480 | 300	+500 | 310	-20	+520 | 310
	Burr	6,150	-20	+560 | 1010	+20	+520 | 950	+510 | 950	-30	+560 | 1000
	Grant	6,300	+30	+220 | 450	-20	+230 | 470	+290 | 480	-50	+230 | 490
	Broadway	5,900	-10	+250 | 430	+10	+180 | 480	+200 | 450	+20	+270 | 480
	I-65	3,400	0	+190 | --	0	+190 | --	+190 | --	0	+190 | --

Observations Based upon the comparison of freeway mainline throughput results, the following observations can be made regarding the corridor throughput for the AM and PM peak hour traffic flow:

- During the 2040 AM peak period, changes to freeway throughputs are mostly derived from the Dynamic Shoulder Lanes strategy and strategy combinations that utilize dynamic shoulder lanes.
- As shown in **Table 6.17**, there is effectively no change in the Ramp Metering strategy and a marginal decrease to locations west of Grant Street in the Variable Speed Limits strategy and the SC3 strategy combination (Ramp Metering + Variable Speed Limits).
- For the remaining strategy of Dynamic Shoulder Lanes and strategy combinations involving dynamic shoulder lanes (SC1, SC2, and SC4): In the 2040 AM scenario, despite the increased capacity along the corridor, the eastbound shoulder lane is not fully utilized due to the lack of congestion. On average, there are less than 100 vehicles per hour in the eastbound shoulder west of Grant Street. However, the utilization is slightly increased (ranging from 150 to 200 vehicles during the peak hour) at Broadway and I-65, which aligns with the minor congestion observed in the Future Baseline scenario. However, in terms of overall throughput, there are only minor increases for these scenarios. In the westbound direction, increased throughput and higher utilization of the shoulder lane (ranging from 90 to 880 vehicles per

hour) are observed. The largest observed volume in the westbound shoulder lane occurs at Burr Street, which corresponds with the area with the most congestion in the Future Baseline scenario.

- Similar to the 2040 AM peak period, changes to freeway throughputs during the 2040 PM peak are mostly derived from the Dynamic Shoulder Lanes strategy and strategy combinations that utilize dynamic shoulder lanes. However, PM throughput increases are higher in comparison to the AM due to greater corridor benefits resulting from these scenarios.
- In the Ramp Metering strategy, moderate increases to eastbound throughput are observed near congestion areas found in the Future Baseline scenario. Mainline segments near Calumet Avenue, Indianapolis Boulevard, Burr Street, and Grant Street see an increase of several hundred vehicles. This increase is likely due to ramp metering improving corridor speeds and traffic operations performance.
- In the Variable Speed Limits strategy and the strategy combination SC3 (Ramp Metering + Variable Speed Limits), there is a moderate decrease of 300 vehicles per hour in eastbound throughput at Torrence Avenue. This decrease aligns with the location of reduced speed causing fewer vehicles to be processed.
- For the remaining strategy of Dynamic Shoulder Lanes and strategy combinations involving dynamic shoulder lanes (SC1, SC2, and SC4), eastbound throughput and shoulder utilization is significantly higher than the AM period. The westbound direction also shows a similar pattern, but the magnitude is less significant. As shown in **Table 6.18**, these scenarios all have the highest eastbound shoulder utilization at Indianapolis Boulevard, ranging from 1450 to 1650 vehicles per hour. In the westbound direction, the corridor section at Burr Street has the highest shoulder utilization, ranging from 950 to 1000 vehicles per hour. These locations both correspond to the highest throughput increases along the corridor.

Travel Times (Minutes)

Travel times were obtained from the traffic operations model for three key sub-routes as discussed in **Section 5.1.2 Corridor-Level Measures of Effectiveness.** Travel times for the AM and PM peak hours were compared between the Future Baseline scenario and the traffic operations TSMO strategies as well as strategy combinations for each direction of travel. Results for each sub-route are provided as tables in the subsequent sections.

Corridor Travel Times

Results: Corridor travel times represent the end-to-end east-west route from approximately IL 394 to I-65. The time differences on this route between each traffic operations TSMO strategy as well as strategy combination and the Future Baseline scenario are presented in **Table 6.19** and **Table 6.20**.

Table 6.19: 2040 AM Corridor Travel Times (Minutes)

					SC1	SC2	SC3	SC4
	Base	RM	DSL	VSL	DSL RM	DSL VSL	RM VSL	DSL RM VSL
	Abs. (Mins)	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Westbound	16.9	0.0 (0%)	0.2 (1%)	0.1 (1%)	0.1 (1%)	0.2 (1%)	0.0 (0%)	0.2 (1%)
Eastbound	17.0	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)

Table 6.20: 2040 PM Corridor Travel Times (Minutes)

					SC1	SC2	SC3	SC4
	Base	RM	DSL	VSL	DSL RM	DSL VSL	RM VSL	DSL RM VSL
	Abs. (Mins)	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Westbound	17.6	0.0 (0%)	-0.2 (-1%)	0.1 (0%)	-0.1 (-1%)	-0.1 (-1%)	0.0 (0%)	-0.2 (-1%)
Eastbound	27.8	-1.9 (-7%)	-6.1 (-22%)	0.0 (0%)	-6.6 (-24%)	-6.4 (-23%)	0.1 (0%)	-6.7 (-24%)

Observations: Based upon the comparison of travel times along the corridor, the following observations can be made regarding the average end-to-end trip during the AM and PM peak hour:

- During the 2040 AM peak hour, there is virtually no change to eastbound corridor travel times in all seven scenarios as there is limited congestion to be addressed by the traffic operations TSMO strategies.
- In the westbound direction, there is a 1% increase in travel times for five of the seven scenarios. The increases are seen in the Dynamic Shoulder Lanes strategy and strategy combinations involving dynamic shoulder lanes (SC1, SC2, and SC4). Since this additional lane is posted at 45 miles per hour, vehicles in the shoulder are traveling on average 10 miles per hour slower than the adjacent lanes during periods of minimal congestion. When calculating the average travel time, this likely leads to a slightly higher value.
- During the 2040 PM peak hour, all strategies and strategy combinations provide corridor travel time savings except for the Variable Speed Limits strategy and the SC3 strategy combination (Ramp Metering + Variable Speed Limits). In general, eastbound travel time savings are more significant in comparison to the westbound direction for the remaining strategy combinations.
- The Variable Speed Limits strategy provides limited overall corridor travel time savings, but based on the speed heat maps, improvements to the western end of the corridor are offset by slight worsening of traffic congestion to downstream bottlenecks; likely a result of more vehicles being released from the upstream bottleneck.
- Out of the three individual strategies, the Dynamic Shoulder Lanes strategy provides the largest travel time savings of 22% (6.1 minutes) as measured in the eastbound direction.
- From the strategy combinations, SC1 (Dynamic Shoulder Lanes + Ramp Metering) ranks at the top with 23% (6.6 minutes) of travel time savings as measured in the eastbound direction.
- Lastly, when combining all three individual strategies in strategy combination SC4, model results show a travel time savings of 24% (6.7 minutes), only marginally better than the Dynamic Shoulder Lanes strategy.

Arterial Travel Times

Results: Arterial travel times represent the time to travel along the key north-south arterial routes crossing the freeway with each route consisting of segments including approximately two intersections upstream and downstream of the freeway facility. This metric aims to compare the impacts to local traffic crossing the freeway during the AM and PM peak hour. The average time differences on all arterials for each traffic operations TSMO strategy as well as strategy combination and the Future Baseline scenario are summarized in **Table 6.21** and **Table 6.22** along with the average change to travel time. Detailed results for each arterial are included in **Appendix D.**

Table 6.21: Average Change in 2040 AM Arterial Travel Times (Seconds)

ROUTE					SC1	SC2	SC3	SC4
	Base	RM	DSL	VSL	DSL RM	DSL VSL	RM VSL	DSL RM VSL
	Avg. (sec)	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Arterials	121	0 0%)	0 (0%)	-1 (-1%)	0 (0%)	0 (0%)	-1 (-1%)	0 (0%)

Table 6.22: Average Change in 2040 PM Arterial Travel Times (Seconds)

ROUTE					SC1	SC2	SC3	SC4
	Base	RM	DSL	VSL	DSL RM	DSL VSL	RM VSL	DSL RM VSL
	Avg. (sec)	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Arterials	166	-3 (-1%)	-12 (-7%)	-9 (-5%)	-10 (-6%)	-13 (-8%)	-6 (-3%)	-8 (-5%)

Observations: Based upon the comparison of travel times along key arterials, the following observations can be made regarding the impacts to arterial streets crossing the freeway during the AM and PM peak hour:

- Generally, there are minor differences in key arterial travel times during the 2040 AM peak period, and greater reductions in the 2040 PM peak period. In the PM, the Dynamic Shoulder Lanes strategy and strategy combinations with dynamic shoulder lanes provide the greatest reduction since increased capacity on the corridor minimizes spillbacks of entrance-ramp traffic onto the local street network. On the contrary, the Ramp Metering strategy and strategy combinations with ramp metering prioritize the corridor, leading to increased delay to entrance-ramp and local street traffic.

2040 AM

- During the 2040 AM peak period, all strategies and strategy combinations produce a reduction in northbound travel time along Indianapolis Boulevard by approximately five to ten percent.
- The Dynamic Shoulder Lanes strategy and strategy combinations with dynamic shoulder lanes (SC1, SC2, and SC4) have higher increases to arterial travel times at Grant Street and Broadway compared to scenarios without dynamic shoulder lanes. On the contrary, these scenarios with dynamic shoulder lanes result in slightly greater improvements to north-south travel times on Torrence Avenue compared to scenarios without dynamic shoulder lanes.

2040 PM

- During the 2040 PM peak period, all traffic operations TSMO strategies and strategy combinations significantly reduce the southbound travel time along Torrence Avenue by approximately 45 to 55 percent. This reduction likely suggests the Torrence interchange has poor operations during the 2040 PM peak, and any improvements to the corridor will reduce congestion at this location.
- The Dynamic Shoulder Lanes strategy and strategy combinations with dynamic shoulder lanes (SC1, SC2, and SC4) also provide benefits on arterials adjacent to the start and end points of the shoulder facility. Travel times along IL-394 / I-94 experience a reduction ranging from 15 to 25 percent. Reduced eastbound congestion near Torrence Avenue likely leads to this improvement.
- Ramp metering strategies without the addition of dynamic shoulder lanes provide the least benefit to arterial travel times as they penalize the local street network in favor of the corridor. As a result,

northbound travel times on Calumet Avenue in the Ramp Metering strategy and the strategy combination SC3 (Ramp Metering + Variable Speed Limits) are 71 percent and 26 percent higher respectively, in comparison with the Future Baseline.

Entrance Ramp Travel Times

Results: Entrance ramp travel times are measured from the entrance ramp terminal traffic signal to approximately 2-3 miles downstream along the freeway. This metric aims to estimate potential delay or travel time savings for entrance ramp movements between each traffic operations TSMO strategy as well as strategy combination and the Future Baseline scenario. The results of the comparison, shown as differences to the Future Baseline scenario, are summarized in **Table 6.23** and **Table 6.24** along with the average change to travel time. More detailed results for each entrance ramp are provided in **Appendix D**.

Table 6.23: Average Change in 2040 AM Entrance Ramp Travel Times (Seconds)

ROUTE					SC1	SC2	SC3	SC4
	Base	RM	DSL	VSL	DSL RM	DSL VSL	RM VSL	DSL RM VSL
	Avg. (sec)	Δ	Δ	Δ	Δ	Δ	Δ	Δ
All On-Ramps	226	4.8 (2%)	0.2 (0%)	0.6 (0%)	5.0 (2%)	0.3 (0%)	4.2 (2%)	5.0 (2%)
Metered On-Ramps	233	7.8 (3%)	0.9 (0%)	0.8 (0%)	8.6 (4%)	1.0 (0%)	7.3 (3%)	8.7 (4%)

Table 6.24: Average Change in 2040 PM Entrance Ramp Travel Times (Seconds)

ROUTE					SC1	SC2	SC3	SC4
	Base	RM	DSL	VSL	DSL RM	DSL VSL	RM VSL	DSL RM VSL
	Avg. (sec)	Δ	Δ	Δ	Δ	Δ	Δ	Δ
All On-Ramps	388	-19.7 (-5%)	-99.1 (-26%)	-11.1 (-3%)	-89.3 (-23%)	-98.6 (-25%)	-12.8 (-3%)	-93.3 (-24%)
Metered On-Ramps	298	+46.2 (16%)	-18.3 (-6%)	-4.9 (-2%)	-8.3 (-3%)	-15.6 (-5%)	+10.6 (4%)	-13.8 (-5%)

Observations The following observations can be made regarding potential delays or travel time savings for entrance ramp traffic during the AM and PM peak hour:

2040 AM

- Generally, scenarios without the use of ramp metering in the 2040 AM period (the Dynamic Shoulder Lanes strategy, the Variable Speed Limits strategy, and the strategy combination SC2 with Dynamic Shoulder Lanes + Variable Speed Limits) result in better entrance ramp travel times. On the contrary, scenarios with ramp metering (the Ramp Metering strategy as well as the strategy combinations SC3 and SC4) experience a three to four percent increase in travel times at metered locations. The remaining scenarios are effectively the same as the Future Baseline scenario.
- In addition, scenarios with dynamic shoulder lanes produce a significant improvement to the northbound to westbound entrance ramp from I-65 by approximately 15 percent. The additional capacity on the corridor likely improves weaving and merging operations at the entrance ramp locations.

2040 PM

- Similarly in the 2040 PM period, scenarios with ramp metering tend to produce a lower magnitude of benefits to entrance ramp travel times, although this trend is not as distinct as the 2040 AM. Due to the amount of congestion in the PM Future Baseline scenario, variable speed limits and dynamic shoulder lanes can relieve some corridor congestion, which indirectly improves entrance ramp operations. As a result, the implementation of ramp metering may not negatively impact entrance ramp travel times on a broader scale when combined with other traffic operations TSMO strategies. This pattern is illustrated by the strategy combinations SC1 (Dynamic Shoulder Lanes + Ramp Metering) and SC4 (Dynamic Shoulder Lanes + Ramp Metering + Variable Speed Limits). Despite the inclusion of ramp metering in both strategy combinations, there is still a three to five percent decrease in entrance ramp travel times.
- However, in the Ramp Metering strategy, when ramp metering is the sole traffic operations TSMO strategy, eastbound entrance ramps at Calumet Avenue, Indianapolis Boulevard, Kennedy Avenue, and Broadway are more highly penalized through reduced metering rates to maintain stable traffic operations within the corridor. Through ramp metering, eastbound entrance ramp travel times at upstream interchanges such as IL-394 and Torrence Avenue are benefiting from the increased speeds along the corridor. These locations are further improved in scenarios that utilize dynamic shoulder lanes.

Travel Time Reliability

Results: Reliability of each traffic operations TSMO strategy and strategy combination is determined based on the 95th percentile travel time, average travel time, and the planning time index. While there is no individual reliability index, the three metrics can be compared across each scenario to quantify reliability. The results of the reliability analysis for each traffic operations TSMO strategy and strategy combination and the Future Baseline scenario are presented in **Table 6.25** to **Table 6.28**.

Table 6.25: 2040 AM Westbound Travel Time Reliability

					SC1	SC2	SC3	SC4
	Base	RM	DSL	VSL	DSL RM	DSL VSL	RM VSL	DSL RM VSL
Average Speed (MPH)	59.0	59.0	58.0	58.0	58.0	57.9	58.7	58.0
95% Travel Time (mins)	17.0	17.0	17.0	17.0	17.3	17.3	17.0	17.3
Planning Time Index	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 6.26: 2040 AM Eastbound Travel Time Reliability

					SC1	SC2	SC3	SC4
	Base	RM	DSL	VSL	DSL RM	DSL VSL	RM VSL	DSL RM VSL
Average Speed (MPH)	59.0	59.0	59.0	59.0	59.4	59.4	59.3	59.4
95% Travel Time (mins)	17.0	17.0	17.0	17.0	17.1	17.1	17.0	17.1
Planning Time Index	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 6.27: 2040 PM Westbound Travel Time Reliability

	Base	RM	DSL	VSL	SC1 DSL RM	SC2 DSL VSL	SC3 RM VSL	SC4 DSL RM VSL
Average Speed (MPH)	55	55	57	55	57.4	57.3	55.5	57.4
95% Travel Time (mins)	19	19	17	19	17.4	17.4	18.4	17.4
Planning Time Index	1.1	1.10	1.00	1.10	1.00	1.00	1.05	1.00

Table 6.28: 2040 PM Eastbound Travel Time Reliability

	Base	RM	DSL	VSL	SC1 DSL RM	SC2 DSL VSL	SC3 RM VSL	SC4 DSL RM VSL
Average Speed (MPH)	35.0	38.0	45.0	35.0	46.4	45.9	34.8	46.4
95% Travel Time (mins)	31.0	28.0	24.0	30.0	23.1	23.4	31.0	22.8
Planning Time Index	1.8	1.60	1.40	1.70	1.32	1.33	1.77	1.30

Observations: Based upon the comparison of the analysis results related to three subcategories of reliability, the following observations can be made regarding the level of consistency or dependability in travel times along the I-80/94 corridor during the AM and PM peak hour:

2040 AM

- During the 2040 AM period, there are marginal changes to overall reliability in all traffic operations TSMO strategies and strategy combinations.
- Notably in the westbound direction, the average speed for the Dynamic Shoulder Lanes strategy and strategy combinations with dynamic shoulder lanes (SC1, SC2, and SC4) are approximately 0.5 miles per hour slower than the Future Baseline scenario. Since the shoulder lane is posted at 45 miles per hour, vehicles in the shoulder are traveling 10 miles per hour slower than the adjacent lanes during periods of minimal congestion. When calculating the average travel time, this likely leads to a slightly higher value.
- Reliability metrics in the eastbound direction are very similar to the Future Baseline scenario.

2040 PM

- During the 2040 PM period, significant congestion is expected in the Future Baseline scenario. As a result, the traffic operations TSMO strategies and strategy combinations can provide greater benefits compared to the 2040 AM period.
- In the westbound direction, the average speed in the Dynamic Shoulder Lanes strategy and strategy combinations with dynamic shoulder lanes (SC1, SC2, and SC4) are approximately two miles per hour faster, leading to a one minute decrease in the 95% travel time, and an improvement to the planning time index by 0.08 points. The improvements are likely due to the increased capacity on the corridor. The remaining scenarios have similar reliability metrics as the Future Baseline scenario. Strategy combination SC3 (Ramp Metering + Variable Speed Limits) is expected to provide the greatest reliability benefits from the scenarios that do not include dynamic shoulder lanes. However, the improvements are marginal over the Future Baseline.
- Regarding the eastbound direction, all traffic operations TSMO strategies and strategy combinations provide reliability benefits over the Future Baseline scenario. Similar to the westbound direction, the

Dynamic Shoulder Lanes strategy and strategy combinations with dynamic shoulder lanes (SC1, SC2, and SC4) provide significant improvements. Average travel speeds are approximately 30 percent higher, leading to a 25 percent decrease in travel times and a 0.5 point improvement in the planning time index. The combination of all three individual traffic operations TSMO strategies in SC4 is ranked the best in terms of reliability. It can be inferred that the Dynamic Shoulder Lanes strategy is superior among the individual traffic operations TSMO strategies. The Ramp Metering strategy provides moderate improvements to reliability since this strategy uses a slow release of entrance ramp vehicles to minimize turbulent operations on the corridor. The Variable Speed Limits strategy produces minor improvements to traffic operations but is expected to increase safety at congestion points. Notably, very minor benefits were garnered from strategy combination SC3 (Ramp Metering + Variable Speed Limits). The integration of ramp metering and variable speed limits seems to yield limited synergies to traffic operations on the corridor.

6.2.2 Summary

Based on the key findings for each performance metric as presented in the above section, the qualitative rating system described in Section 5.1.3 was applied to synthesize the results, as shown in the legend below. A brief summary of the assessment results for each traffic operations TSMO strategy and strategy combination is provided below along with the qualitative rating for the selected performance metrics.

LEGEND	
↑	Significantly Better
↗	Moderately Better
→	No Change
↘	Moderately Worse
↓	Significantly Worse

Figure 6.4: Qualitative Rating System

Ramp Metering

ID	FREEWAY SPEED	FREEWAY THROUGHPUT	TRAVEL TIME SAVINGS				TRAVEL TIME RELIABILITY	TRAFFIC DIVERSION TO LOCAL STREETS
			Freeway	Municipal	Ramp	Arterial		
	↗	↗	↗	↘	↘	→	↗	↘

Moderate improvements to the I-80/94 mainline were observed in terms of the traffic operations metrics including speed, travel time, and reliability; however, increased diversion to the local street network was observed to occur, particularly during the PM peak period when demand for the freeway is at its highest. Savings to freeway travel time are dampened from a network perspective due to the increase in trips using the local street network as noted in the network VHT metrics. Operationally, the ramp meter processing rate could be adjusted to improve or worsen freeway traffic performance at the benefit or disbenefit to the municipal network.

Dynamic Shoulder Lanes

ID	FREEWAY SPEED	FREEWAY THROUGHPUT	TRAVEL TIME SAVINGS				TRAVEL TIME RELIABILITY	TRAFFIC DIVERSION TO LOCAL STREETS
			Freeway	Municipal	Ramp	Arterial		
	↑	↑	↑	↗	↗	↗	↑	→

Significant improvements to virtually all traffic operations metrics were observed with the increased capacity to the freeway. Analysis of travel demand from the NIRPC model indicates the corridor becomes more attractive to drivers and results in increased trips using the I-80/94 corridor. The traffic operations model results show that upwards of 1,500 more vehicle per hour may be drawn to the corridor, increasing VMT by up to 7% on the I-80/94 corridor. Despite this increased travel demand, the traffic operations performance of the freeway still improves considerably over the Base during the PM peak period and remains stable during the relatively uncongested AM peak period; despite increased travel demands. Utilization of the dynamic shoulder lane is highest near areas of congestion with the highest volume observed in the 2040 eastbound direction during the PM peak hour. Major bottlenecks along the corridor are generally resolved through the application of the dynamic shoulder lane which also improves the corridor reliability. During the AM peak period, the dynamic shoulder lane draws trips to the corridor but does not improve upon the baseline traffic performance as there are few notable congested areas during this time period. This additional traffic results in an overall increase to network travel time. The dynamic shoulder lane during the AM peak period simply serves to provide increased throughput on the corridor while maintaining approximately the same travel time and reliability as the Future Base scenario.

Variable Speed Limits

ID	FREEWAY SPEED	FREEWAY THROUGHPUT	TRAVEL TIME SAVINGS				TRAVEL TIME RELIABILITY	TRAFFIC DIVERSION TO LOCAL STREETS
			Freeway	Municipal	Ramp	Arterial		
	→	↗	→	↑	→	↗	↗	→

Moderate to neutral improvements to traffic operations metrics were observed for the variable speed limit system. Freeway speeds were shown to improve only slightly; primarily localized to the area directly adjacent to the start of the VSL system in the eastbound direction. Congestion near Torrence Avenue and IL 394 interchange was notably remediated which provided benefits to municipal network congestion stemming from the entrance and exit ramps adjoining the I-80/94 corridor. The improvement to the western end of the corridor is partially offset by the increase to congestion to downstream bottlenecks (in the eastbound direction); likely due to more traffic being released upstream.

SC1 – Dynamic Shoulder Lanes + Ramp Metering

ID	FREEWAY SPEED	FREEWAY THROUGHPUT	TRAVEL TIME SAVINGS				TRAVEL TIME RELIABILITY	TRAFFIC DIVERSION TO LOCAL STREETS
			Freeway	Municipal	Ramp	Arterial		
SC1	↑	↑	↑	↗	→	↗	↑	→

Combined traffic operations performance of the Dynamic Shoulder Lanes and Ramp Metering system yielded similar improvements to the Dynamic Shoulder Lanes strategy with marginally better corridor travel times and speeds. Reliability of the corridor is also improved with the combined systems compared to the strategies in isolation. Entrance ramp meters were observed to moderate the increased attraction to the corridor from the dynamic shoulder lane.

SC2 – Dynamic Shoulder Lanes + Variable Speed Limits

ID	FREEWAY SPEED	FREEWAY THROUGHPUT	TRAVEL TIME SAVINGS				TRAVEL TIME RELIABILITY	TRAFFIC DIVERSION TO LOCAL STREETS
			Freeway	Municipal	Ramp	Arterial		
SC2	↑	↑	↑	↗	↗	↗	↑	→

Combined traffic operations performance of the Dynamic Shoulder Lanes and Variable Speed Limit system yielded similar improvements to just the Dynamic Shoulder Lanes strategy. The Variable Speed Limit system did not display notable synergies to traffic operations as the major congested regions are generally resolved through application of the Dynamic Shoulder Lanes already.

SC3 – Ramp Metering + Variable Speed Limits

ID	FREEWAY SPEED	FREEWAY THROUGHPUT	TRAVEL TIME SAVINGS				TRAVEL TIME RELIABILITY	TRAFFIC DIVERSION TO LOCAL STREETS
			Freeway	Municipal	Ramp	Arterial		
SC3	↗	↗	→	↗	↘	→	→	↘

Only moderate improvements to traffic operations performance were observed from the combination of the Ramp Metering and Variable Speed Limits strategies (SC3). There does not appear to be notable synergies between the two TSMO strategies. Improvements to the municipal network congestion were observed though the magnitude of change appears to be less than with just the Variable Speed Limits strategy in isolation.

SC4 – Dynamic Shoulder Lanes + Variable Speed Limits + Ramp Metering

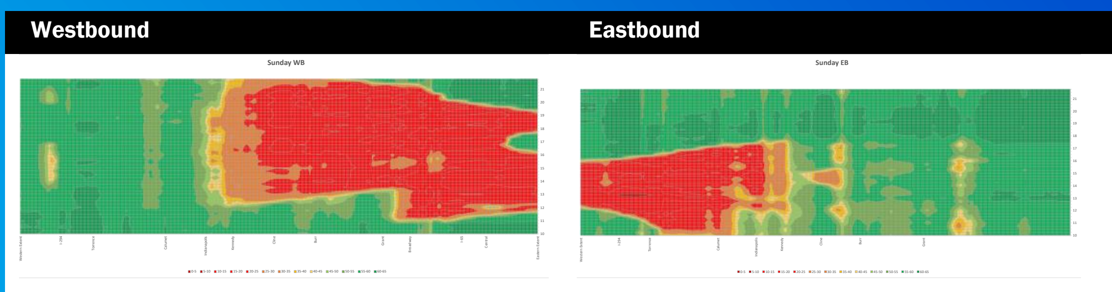
ID	FREEWAY SPEED	FREEWAY THROUGHPUT	TRAVEL TIME SAVINGS				TRAVEL TIME RELIABILITY	TRAFFIC DIVERSION TO LOCAL STREETS
			Freeway	Municipal	Ramp	Arterial		
SC4	↑	↑	↑	↗	↗	↗	↑	→

The combination of all three traffic operations TSMO strategies yielded the largest improvements to traffic operations metrics including speed, travel time, and reliability. The primary driver behind the improvements appears to be the Dynamic Shoulder Lanes strategy; however, complementary benefits were observed through application of the Ramp Metering and Variable Speed Limit systems as a consolidated package. The attraction of additional vehicles during the PM peak period to the corridor does not yield an increase to network travel time as alleviation of existing bottlenecks compensates for the additional trips on the I-80/94 corridor.

WEEKEND (SUNDAY) SUPPLEMENTARY ANALYSIS (EXAMPLE)

Application of traffic operations TSMO strategies and strategy combinations during the Sunday period were assessed at a high level. Observed congestion during this time period is significant, and for the summer season there are considerable bottlenecks lasting from approximately 10 AM to 10 PM. Generally, Sunday trip lengths are longer than those of the typical weekday, suggesting a greater portion of inter-state travel.

To quantify the impacts of traffic operations TSMO strategies during the Sunday period, a high-level microsimulation analysis was undertaken using the same methodology as the typical weekday analysis. Non-TSMO geometric modifications including the Broadway interchange and I-65 interchange modifications were incorporated into the base model. The speed heatmaps for the Base Sunday period are shown in the figure below with temporal extents from 10 AM to 10 PM. As shown, there is significant congestion in both the westbound and eastbound directions, with congestion between the Indianapolis Boulevard interchange and the eastern study limits for westbound traffic and from the Kennedy Avenue interchange to the western study limits for eastbound traffic.



The leading traffic operations TSMO strategies were incorporated into the Sunday period analysis. The use of the Dynamic Shoulder Lanes and Ramp Metering strategies were analyzed as separate scenarios. High-level results in terms of network travel time as well as corridor travel time and speed are presented below. The following observations are compared against the Base Sunday scenario.

Network Vehicles Hours Traveled

Network level metrics represent cumulative impacts to network traffic for the entire study area. Measures of effectiveness are aggregated for high-level comparison.

- The use of Dynamic Shoulder Lanes resulted in a significant decrease of 20% to total vehicle travel time[1].
- The use of Ramp Metering resulted in a moderate decrease of 5% to total vehicle travel time.

Corridor

The corridor is defined as the freeway segment between the interchanges at IL-394 and Central Avenue. The following results are averaged between the westbound and eastbound directions.

Average Travel Time

- The use of Dynamic Shoulder Lanes resulted in a significant **improvement of 20%** to east-west corridor travel times.
- The use of Ramp Metering resulted in a moderate **improvement of 7%** to east-west in corridor travel times

Average Speed

- The use of Dynamic Shoulder Lanes resulted in a significant **improvement of 15%** to east-west corridor travel times
- The use of Ramp Metering resulted in a moderate **improvement of 6%** to east-west in corridor speed.

Overall, the results of the high-level analysis for the Sunday period demonstrate considerable traffic operations benefits resulting from the proposed leading TSMO strategies. This corroborates the findings for the typical weekday analysis.

1) Travel demand was not modified for the Sunday DSL assessment

6.2.3 Traffic Operations TSMO Strategies Benefit-Cost Analysis

The detailed traffic operations data was used to generate traffic operations Present Value (PV) benefits as well as to determine a prioritization of projects based on the resulting Benefit-Cost Ratio (BCR). Travel time savings for the I-80/94 corridor were converted to monetary benefits using the methodology detailed in **Section 5.1.4.** For this analysis, it was assumed that the year-over-year change to travel time savings between the Base year and the Future year would be linear in scope and that benefits would only start to accrue in 2025 and last to 2040 inclusively. Based on these assumptions, the 2021 present value benefits in dollars for the seven traffic operations TSMO strategies and strategy combinations are provided in **Table 6.29** below (with travel time savings added from **Table 6.19** and **Table 6.20** for reference, and negative values shown in red to represent an increase in travel time).

> The annual cost of delay (in terms of value-of-time) caused by recurrent non-incident congestion within the study corridor in 2019 was estimated to be over **$300 million.**

Table 6.29: Present Value Benefits to I-80/94 of Traffic Operations TSMO Strategies and Strategy Combinations

STRATEGY	DESCRIPTION	CORRIDOR TRAVEL TIME SAVINGS				PV BENEFITS ($M)
		2040 AM (MIN)		2040 PM (MIN)		
		WB	EB	WB	EB	
	Ramp Metering	0	0	0	1.9	$93.6
	Dynamic Shoulder Lanes	-0.2	0	0.2	6.1	$286.9
	Variable Speed Limits	-0.1	0	-0.1	0	$85.3
SC1	Dynamic Shoulder Lanes + Ramp Metering	-0.1	0	0.1	6.6	$334.6
SC2	Dynamic Shoulder Lanes + Variable Speed Limits	-0.2	0	0.1	6.4	$354.6
SC3	Ramp Metering + Variable Speed Limits	0	0	0	-0.1	$95.0
SC4	Dynamic Shoulder Lanes + Ramp Metering + Variable Speed Limits	-0.2	0	0.2	6.7	$355.3

The cost estimates for each traffic operations TSMO strategy and strategy combination are described in detail in **Section 4.1** which include implementation as well as operations and maintenance costs. The full year-over-year (YoY) costs are detailed in **Appendix D** with the summary present value costs presented in **Table 6.30.** For this analysis, design and construction was assumed to commence in 2023 and last for approximately two years with 50% of the cost incurred in the first year (2023) and the remaining 50% in the second year (2024). All values are presented in 2021 dollars.

Table 6.30: Present Value Costs of Traffic Operations TSMO Strategies and Strategy Combinations

STRATEGY	DESCRIPTION	PV COSTS ($M)
	Ramp Metering	$6.5
	Dynamic Shoulder Lanes	$77.4
	Variable Speed Limits	$22.1
SC1	Dynamic Shoulder Lanes + Ramp Metering	$83.2
SC2	Dynamic Shoulder Lanes + Variable Speed Limits	$83.0
SC3	Ramp Metering + Variable Speed Limits	$27.4
SC4	Dynamic Shoulder Lanes + Ramp Metering + Variable Speed Limits	$86.5

Based on the present value benefits and costs, the BCR and NPV were calculated for the seven traffic operations TSMO strategies and strategy combinations, as presented in **Table 6.31** below (with travel time savings added from **Table 6.19** and **Table 6.20** for reference, and negative values shown in red to represent an increase in travel time). As shown in the table below, from a freeway standpoint, ramp metering exhibits the highest BCR at over 14. Other TSMO scenarios yield similar BCR in the three times multiplier range. Interestingly, despite incurring the highest BCR, ramp metering only offers approximately one-third the NPV benefits associated with scenarios using dynamic shoulder lanes. The dynamic shoulder lane scenarios, while more expensive, provide the highest absolute benefits in terms of NPV.

Table 6.31: Benefit-Cost Ratio and NPV from Traffic Operations TSMO Strategies and Strategy Combinations

STRATEGY	DESCRIPTION	CORRIDOR TRAVEL TIME SAVINGS				BCR	NPV ($M)
		2040 AM (Min)		2040 PM (Min)			
		WB	EB	WB	EB		
	Ramp Metering	0	0	0	1.9	14.4	$87.1
	Dynamic Shoulder Lanes	-0.2	0	0.2	6.1	3.7	$209.5
	Variable Speed Limit	-0.1	0	-0.1	0	3.9	$63.2
SC1	Dynamic Shoulder Lanes + Ramp Metering	-0.1	0	0.1	6.6	4.0	$251.4
SC2	Dynamic Shoulder Lanes + Variable Speed Limits	-0.2	0	0.1	6.4	4.3	$271.6
SC3	Ramp Metering + Variable Speed Limits	0	0	0	-0.1	3.5	$67.6
SC4	Dynamic Shoulder Lanes + Ramp Metering + Variable Speed Limits	-0.2	0	0.2	6.7	4.1	$268.8

6.3 TRAFFIC SAFETY TSMO STRATEGIES

Safety benefit assessment results for the traffic safety TSMO strategies are presented in this sub-section. The independent implementation of variable speed limits and queue warning system were assessed quantitatively using the RoadHAT software. Conversely, lane control was assessed qualitatively due to a lack of documented crash modification factors for the independent implementation of such system.

> The average annual crash cost for the study corridor is approximately $336 million in 2021 dollars.

Dynamic Lane Control

As described in **Section 4.2**, dynamic lane control involves dynamically closing or opening individual traffic lanes as warranted and providing advance warning of the closure(s) through the use of lane control signals, in order to safely merge traffic into adjoining lanes. Real-time incident and congestion data are used to control lane use ahead of the lane closure(s) and dynamically manage the location.

Dynamic lane control can help reduce the potential for rear end crashes, which is the predominant crash type along the study corridor, as the advance warning of congestion and/or incidents will provide drivers more time to respond and slow down. Also, when used in conjunction with a variable speed limit system to manage congestion and/or incidents, speeds are harmonized and sudden large speed reductions are minimized, which will further help reduce the potential for rear end and secondary crashes.

Dynamic lane control can also help reduce the potential for side swipe crashes, which represent the second highest number of crashes along the study corridor, as any necessary lane change movements related to the lane closure(s) are carefully directed by the overhead lane signs.

Variable Speed Limits

In the assessment of safety benefits for variable speed limit, it was assumed that the system would be in operation on weekdays (Monday through Friday) in the AM and PM peak periods. An 8% reduction in total crashes was applied, as discussed in the assessment approach in **Section 5.2**. The resulting safety benefits for the study corridor are summarized in **Table 6.32**, with segment-based results provided in **Appendix D**.

Table 6.32: Estimated Safety Benefits for Variable Speed Limits

STRATEGY	OBSERVED CRASHES (2017-2019)				CRASHES SAVED				PRESENT VALUE BENEFIT
	Fatal + Incap. Injury	Non-Incap. + Possible Injury	Property Damage Only	Total	Fatal + Incap. Injury	(Incap.) + Non-Incap. + Possible Injury	Property Damage Only	Total	($ Million)
Variable Speed Limit	78	99	1,333	1,510	4.0	3.4	37.9	45.2	267.6

Taking into consideration the implementation as well as operations and maintenance costs presented in **Section 4.0**, the benefit-cost results for the independent application of the Variable Speed Limits strategy are presented in **Table 6.33**. Both the net present value and benefit-cost ratio indicate that the strategy is economically viable for the study corridor.

Table 6.33: Benefit-Cost Results for Variable Speed Limits

STRATEGY	PRESENT VALUE BENEFIT	PRESENT VALUE COST	NET PRESENT VALUE	BCR
	($ Million)	($ Million)	($ Million)	
Variable Speed Limits	267.6	22.1	245.5	12.1

Queue Warning System

In the assessment of safety benefits for the queue warning system, it was assumed that the strategy would be in operation on weekdays (Monday through Friday) from 6:00 am to 9:00 pm. A 16% reduction in rear-end injury crashes and a 16% increase in rear-end property damage only (PDO) crashes were applied, as discussed in the assessment approach in **Section 5.2**. The 16% reduction in injury crashes applies to all three severity levels, including incapacitating, non-incapacitating, and possible injury. As the RoadHAT software does not evaluate benefits for each injury severity level separately but considers non-incapacitating and possible injury crashes at one average crash cost, and fatal and incapacitating crashes at another (much higher) average crash cost, the incapacitating crashes were added to the lower severity category for analysis purposes. The resulting estimated safety benefits may be considered conservative as, in reality, incapacitating injury crashes would be associated with a higher average crash cost than the lower severity injury crashes. The safety benefits for the study corridor are summarized in **Table 6.34**, with segment-based results provided in **Appendix D**.

Table 6.34: Estimated Safety Benefits for Queue Warning System

STRATEGY	OBSERVED REAR END CRASHES (2017-2019)					REAR END CRASHES SAVED				PRESENT VALUE BENEFIT
	Fatal	Incap. Injury	Non-Incap. + Possible Injury	Property Damage Only	Total	Fatal	(Incap.) + Non-Incap. + Possible Injury	Property Damage Only	Total	($ Million)
Queue Warning System	-	65	95	1,228	1,388	-	9	-70	-61	11.4

Taking into consideration the implementation as well as operations and maintenance costs presented in **Section 4.0**, the benefit-cost results for the independent application of queue warning system are presented in **Table 6.35**. Both the net present value and benefit-cost ratio indicate that the strategy is not economically viable for the study corridor. However, as noted earlier, the benefits may be under-estimated. Also, some of the systems costs may be reduced if queue warning system is implemented in conjunction with other strategies, which may improve the benefit-cost results. Thus, queue warning system should be brought forward for further assessment and consideration.

Table 6.35: Benefit-Cost Results for Queue Warning System

STRATEGY	PRESENT VALUE BENEFIT	PRESENT VALUE COST	NET PRESENT VALUE	BCR
	($ Million)	($ Million)	($ Million)	
Queue Warning System	11.4	14.7	(3.30)	0.78

6.4 EVENT MANAGEMENT TSMO STRATEGIES

The assessment of the event management related TSMO strategies involved a combination of:

- Traffic operations modeling outputs quantifying benefits related to the application of some TSMO strategies when a representative incident is modeled.
- Examples research on potential reduction in incident identification and response due to system enhancements and new procedures.

This section details the traffic operations modeling outputs quantifying benefits related to the application of TSMO strategies to address incidents on the corridor. Two applications of incident management were modeled including:

- A combination of traffic and event management supplementary strategies (assuming the strategies combined would improve incident clearance times by at least 5 minutes).

  For the purposes of this analysis, it is assumed that a combination of the following event management related strategies would generate a potential reduction in incident clearance times by at least 5 minutes (or more) on average:
  - TRIP
  - Hoosier Helper Enhancements
  - Complementary Strategies
  - Work Zone Management

- Event-Based Dynamic Shoulder Lanes

  For the purposes of this analysis, it is assumed that the same combination of event management related strategies would be implemented along with a lane control system to allow temporary use of large segments of the shoulders to allow traffic to divert around a lane blockage.

6.4.1 Quantitative Incident Traffic Operations Analysis (Incident Management)

In order to quantify the potential traffic operations benefits derived from the proposed improvements to incident management, an assessment and characterization of the existing incidents within the corridor was undertaken. Incidents within the corridor are catalogued in two different databases: namely the Gateway Traffic Incident Management System (TIMS) and the INDOT TIMS. Incidents in both databases were recorded for the full 2019 calendar year. In total, 578 unique and applicable incidents were recorded during this timeframe with the majority of the incidents occurring during the AM and PM peak periods. Each event was categorized by direction, time of day, and type of incident as described in **Table 6.36** below.

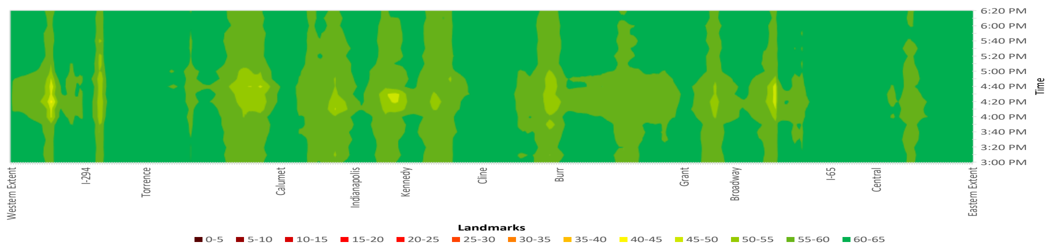
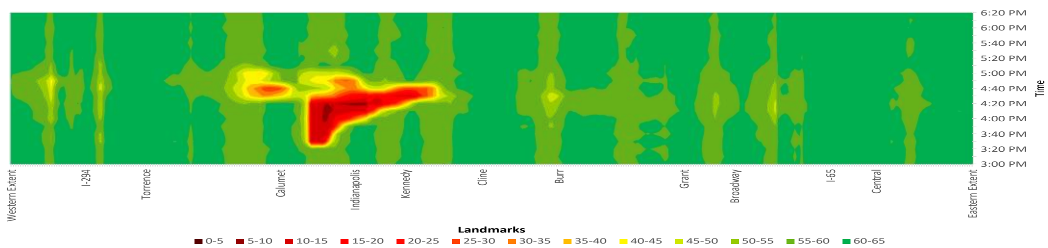
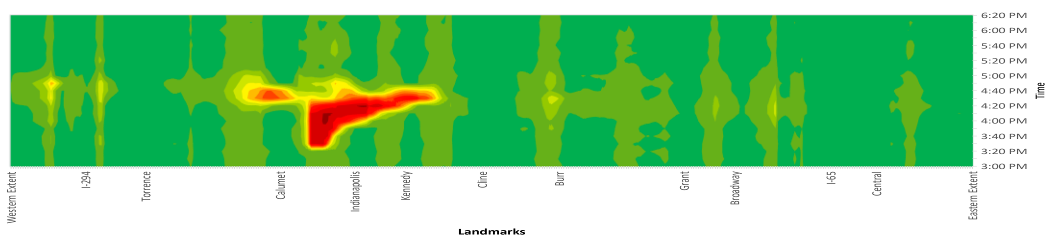
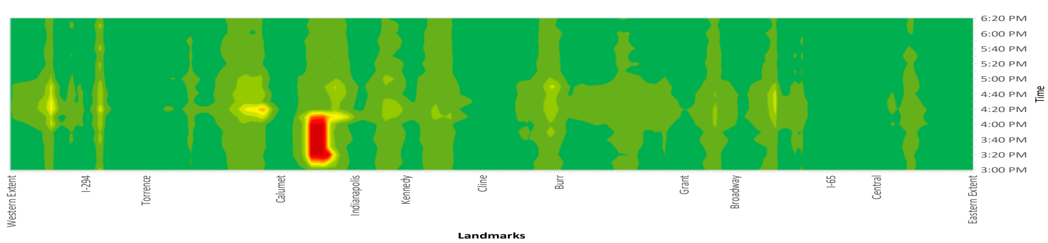
Table 6.36: Observed Incident Occurrences in 2019

DIRECTION	TIME OF DAY	DAY OF WEEK	INCIDENT # LANES CLOSED	
			1	2+
Eastbound	AM	MF	26	18
	PM	MF	91	42
	Off-Peak	MF	25	17
	AM	Sat	8	4
	PM	Sat	7	9
	Off-Peak	Sat	6	9
	AM	Sun	1	4
	PM	Sun	9	7
	Off-Peak	Sun	2	3
Westbound	AM	MF	40	17
	PM	MF	92	31
	Off-Peak	MF	26	18
	AM	Sat	6	3
	PM	Sat	13	5
	Off-Peak	Sat	2	3
	AM	Sun	2	2
	PM	Sun	21	4
	Off-Peak	Sun	2	3

Note: MF is Monday to Friday

The traffic operations model was applied to the representative incidents as described in **Section 5.3.2**. For reference, **Table 6.37** below shows an example of the speed heat map output for both the Baseline incident and improvement scenarios for a typical one-lane one-hour closure in the westbound direction between Calumet Avenue and Indianapolis Boulevard interchanges during the PM peak period for 2019. As shown, the 5-minute improvement to incident identification, verification, and response yields a small improvement to corridor speed with slightly less congestion shown. The event-based dynamic shoulder lane system; however, yields significant improvements to corridor speed with much of the existing incident congestion mitigated and only localized around the actual incident location.

Table 6.37: Sample Speed Heat Map of Incidents and Improvements

Scenario	Westbound
2019 PM Typical Base	
2019 PM Incident Base (1 Lane Closed for 60 Minutes)	
2019 PM Identification/ Response Improvement (1 Lane Closed for 55 Minutes)	
2019 PM Dynamic Shoulder Lane (1 Lane Closed for 60 Minutes)	

The difference in network travel time between the incident management improvements scenarios and the incident baseline scenarios yielded the travel time savings attributed to either enhanced incident response or event-based dynamic shoulder lanes in the vicinity of the incident. These travel time improvements were then mapped according to the observed incidents on the corridor generated from the Gateway TIMS and INDOT

TIMS databases. The result was the approximate travel time savings incurred for both improvement scenarios during the 2019 and 2040 horizon years as shown in Table 6.38.

Table 6.38: Approximate Annual Travel Time Savings (Hours) from Incident Management Improvements

YEAR	SYSTEM IMPROVEMENT	ESTIMATED ANNUAL TRAVEL TIME SAVINGS (HOURS)
2019	Incident Identification / Verification Response Improvements	39,100
	Event-Based Dynamic Shoulder Lane	487,400
2040	Incident Identification / Verification Response Improvements	66,400
	Event-Based Dynamic Shoulder Lane	1,224,800

The resultant data indicates significant travel time savings being accrued for both improvements with the dynamic shoulder lane exhibiting the largest reduction. In particular, the 2040 horizon year generates substantially more travel time benefits from incident management improvements; likely due to the fact that congestion is much worse in 2040 and therefore incremental improvements to traffic operations yield exponential improvements to network travel time.

The travel time savings were converted to monetary benefits using the same methodology to analyze the traffic operations TSMO strategies and strategy combinations as detailed in Section 5.1.4. For this analysis it was also assumed that the year-over-year change to travel time savings between the Base year and the Future year would be linear in scope and that benefits would only start to accrue in 2025 and continue for 16 years. Based on these assumptions, the 2021 present value benefits in dollars is provided in Table 6.39 below.

Table 6.39: Present Value Benefits from Incident Management Improvements

SYSTEM IMPROVEMENT	PRESENT VALUE ($ MILLION)
Incident Identification / Verification / Response Improvements	$16.7
Event-Based Dynamic Shoulder Lane	$280.0

Costs associated with incident management improvements are highlighted in Table 6.40 below. Incident identification/verification and response improvements are associated with several complementary TSMO strategies described in Section 4.1.6 including but not limited to:

- TRIP
- Hoosier Helper Enhancements
- Complementary Strategies
  - Providing Optimal ITS device deployment
  - Optimize Data and Image sharing
  - Center to Center Interfaces
  - Computer Aided Dispatch (CAD) Integration
  - Maintenance and Emergency Response Agency Access to CCTV
- Work Zone Management

Table 6.40: Present Value Costs from Incident Management Improvements

SYSTEM IMPROVEMENT	PRESENT VALUE ($ MILLION)
Incident Identification / Verification / Response Improvements	$10.8
Event-Based Dynamic Shoulder Lane	$77.4

Based on the present value benefits and costs, the BCR were calculated for the two improvement strategies and are shown in **Table 6.41** below. As shown, the Incident Identification / Verification / Response improvements yield a BCR of 1.6 and a NPV of approximately $5.9 million. The event-based dynamic shoulder lane yields a higher BCR of 3.6 and NPV is substantially higher at approximately $202.6 million.

Table 6.41: Benefit-Cost Ratio and NPV from Incident Management Improvements

SYSTEM IMPROVEMENT	BCR	RANK	NPV ($ MILLION)
Incident Identification / Verification / Response Improvements	1.6	2	$5.9
Event-Based Dynamic Shoulder Lane	3.6	1	$202.6

6.4.2 Qualitative Assessment

A brief summary of the potential benefits that can be achieved through several improvement strategies related to event management are provided below to augment the quantitative analysis above.:

TRIP

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 the benefits 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 that were realized over the first 18 months of operation.

Complementary Strategies

While these strategies are not a key aspect of this study, each can play a role in further improving the operation and efficiency of the corridor with respect to safety, event and incident response, and travel time dissemination. It is also noted that INDOT already implements many of these strategies throughout the state.

Lane Control

As part of the development of the TSMO strategies for the I-80/94 corridor, several stakeholders were consulted including maintenance and operations staff in both Indiana and Illinois. One of the key considerations that was mentioned by many stakeholders was the importance of being able to maintain the use of the travel lanes in this corridor. Several stakeholders indicated that a good portion of the congestion in the corridor is the result of incidents or maintenance activities (snow removal, roadway maintenance, drainage maintenance, and the removal of debris were all mentioned as key considerations). The stakeholders also indicated that the ability to respond to, and quickly and safely clear incidents in the corridor, is a very important consideration.

This input from the stakeholders validates the consideration of a lane control system which will support safe and efficient incident management and roadway maintenance, while improving traffic flow in the area.

6.5 ASSESSMENT SUMMARY

A brief summary of the assessment of each improvement strategy is provided in the sub-sections below.

Although the potential benefits have largely been identified for each individual strategy under the primary strategy intent, it is recognized that other benefits are associated with the improvement strategies being considered. Furthermore, these combined benefits may be larger than the sum of the individual benefits identified in the assessment undertaken for this study. Therefore, the benefits summarized below for some strategies only represent the benefits associated with the primary intent of the improvement strategy and that other benefits could be accrued. For example, ramp metering may produce safety benefits associated with a reduction in congestion, however, only the traffic operations related benefits have been quantified as part of the overall assessment.

6.5.1 Non TSMO Improvement Strategies

Broadway Interchange and I-65 Interchange Modifications

The Broadway interchange and I-65 interchange modifications were identified to assist in alleviating congestion for eastbound I-80/94 traffic that stems from various weaving and lane balance traffic operations issues. The proposed improvements were assessed for the Existing and Future horizon years using the traffic operations model. The results indicate that the proposed modifications yield significant improvements to speed, travel time, and reliability in the vicinity of the Broadway interchange and I-65 Interchange (EB exit to I-65) . Corridor travel time savings of up to 10 minutes during the PM peak period were identified along with approximately a 5% reduction to total vehicle hours traveled on the I-80/94 corridor.

Travel time savings were converted to monetary benefits and were combined with costs to generate the BCR and NPV. The projected BCR and NPV are shown in **Table 6.42** below. The Broadway interchange and I-65 interchange modifications are forecast to achieve a BCR of 36.2 with a NPV of approximately $144.4 million.

Table 6.42: Benefit-Cost Ratio and NPV from Broadway Interchange and I-65 Interchange Modifications

DESCRIPTION	BCR	NPV ($ MILLION)
Broadway Interchange and I-65 Interchange Modifications	36.2	$144.4

Overall, the Broadway interchange and I-65 interchange modifications and the resultant capacity improvements would complement the TSMO strategies as the recurrent eastbound congestion caused by the I-65 exit weaving and lane balance traffic operations issues are at the downstream end of the corridor. Therefore, any improvements in the upstream bottlenecks due to TSMO strategy implementation may just allow more traffic to reach this bottleneck and make it even worse unless these downstream issues are remediated.

Signing Enhancements

Enhanced advisory signs approaching the existing left lane merge location at the eastern limits of the project are anticipated to improve traffic operations and traffic safety. This improvement strategy is consistent with INDOT design manual guidance.

The installation of interchange sequence signs is proposed as another measure to improve traffic operations within the study corridor. These guide signs will provide additional information to drivers to allow more informed choices with respect to lane usage, thereby potentially improving traffic operations as the lane utilization could be more equally distributed or proportional across all lanes.

6.5.2 Traffic Operations

Three individual traffic operations TSMO strategies with an additional four strategy combinations generated from permutations of the individual strategies were evaluated using the traffic operations model. A summary of the seven traffic operations TSMO scenarios is provided in **Table 6.43**.

Table 6.43: Traffic Operations TSMO Strategies and Strategy Combinations

PROJECT	DESCRIPTION
	Ramp Metering
	Dynamic Shoulder Lanes
	Variable Speed Limits
SC1	Dynamic Shoulder Lanes + Ramp Metering
SC2	Dynamic Shoulder Lanes + Variable Speed Limits
SC3	Ramp Metering + Variable Speed Limits
SC4	Dynamic Shoulder Lanes + Ramp Metering + Variable Speed Limits

Based on the traffic operations measures of effectiveness and key findings, the qualitative rating system described in **Section 5.1.3** was applied to synthesize the results for each traffic operations strategy and strategy combination listed in **Table 6.43**. The summary table improvements or lack thereof are relative to the Base Case scenario. In general, the traffic operations TSMO scenarios were shown to provide notable benefits to travel time, throughput, speed, and reliability amongst other metrics. The application of the dynamic shoulder lane appears to provide the best improvement to traffic operations despite the increased attraction of trips to I-80/94. Ramp metering performed well in terms of freeway operations but exhibited minor disbenefits to the local street network. Combinations of the traffic operations TSMO strategies yielded only neutral to moderate additional improvements to traffic operations performance although implementation of all three individual strategies (SC4) did yield the best traffic operations results.

The Qualitative Rating System applied in summary **Table 6.45** is shown below in **Table 6.44**.

Table 6.44: Qualitative Rating System

LEGEND	
↑	Significantly Better
↗	Moderately Better
→	No Change
↘	Moderately Worse
↓	Significantly Worse

Table 6.45: Summary of Traffic Operations TSMO Strategies and Strategy Combinations Performance

SUMMARY METRIC		RAMP METERING	DYNAMIC SHOULDER LANES	VARIABLE SPEED LIMITS	SC1 DYNAMIC SHOULDER LANES + RAMP METERING	SC2 DYNAMIC SHOULDER LANES + VARIABLE SPEED LIMITS	SC3 RAMP METERING + VARIABLE SPEED LIMITS	SC4 DYNAMIC SHOULDER LANES + RAMP METERING + VARIABLE SPEED LIMITS
Freeway Speed		↗	↑	→	↑	↑	↗	↑
Freeway Throughput		↗	↑	↗	↑	↑	↗	↑
Travel Time Savings	Freeway	↗	↑	→	↑	↑	→	↑
	Municipal	↘	↗	↑	↗	↗	↗	↗
	Ramp	↘	↗	→	→	↗	↘	↗
	Arterial	→	↗	↗	↗	↗	→	↗
Travel Time Reliability		↗	↑	↗	↑	↑	→	↑
Traffic Diversion to Local Streets		↘	→	→	→	→	↘	→

Based on the present value benefits and costs, the BCR and NPV were calculated for the seven traffic operations TSMO strategies and strategy combinations, as shown in Table 6.46 below. All traffic operations TSMO strategies and strategy combinations yield positive NPV and BCR greater than 1.0. From a freeway standpoint, the Ramp Metering strategy achieves the highest BCR with the strategy combination SC2 (Dynamic Shoulder Lanes + Variable Speed Limits) ranking second best. Notably, while the Ramp Metering strategy has the highest BCR, the NPV garnered from the improvement is only approximately one-third of the amount stemming from scenarios incorporating dynamic shoulder lanes.

Table 6.46: Benefit-Cost Ratio and NPV from Traffic Operations TSMO Strategies and Strategy Combinations

STRATEGY	DESCRIPTION	BCR	NPV ($ MILLION)
	Ramp Metering	14.4	$87.1
	Dynamic Shoulder Lanes	3.7	$209.5
	Variable Speed Limit	3.9	$63.2
SC1	Dynamic Shoulder Lanes + Ramp Metering	4.0	$251.4
SC2	Dynamic Shoulder Lanes + Variable Speed Limits	4.3	$271.6
SC3	Ramp Metering + Variable Speed Limits	3.5	$67.6
SC4	Dynamic Shoulder Lanes + Ramp Metering + Variable Speed Limits	4.1	$268.8

6.5.3 Traffic Safety

The Variable Speed Limits strategy is anticipated to provide significant safety benefits in the form of reduced crashes, while the queue warning system strategy is associated with unfavorable benefit-cost results. However, as noted earlier, the benefits may be under-estimated, as the incapacitating injury crashes were evaluated at a lower average crash cost than what it might be in reality. The results for the traffic safety TSMO strategies are as follows:

- Dynamic Lane Control* N/A
  *(system typically provides safety benefits in conjunction with other strategies)
- Variable Speed Limits BCR = 12.1 NPV = $245.5 M
- Queue Warning System BCR = 0.78 NPV = ($3.30 M)

It is noted that the Variable Speed Limits strategy also generates traffic operations related benefits. In addition, a variable speed limit system is a key component of the Dynamic Shoulder Lane strategy.

6.5.4 Event Management

Quantitative assessment of two event management TSMO strategy combinations were evaluated using the traffic operations microsimulation model. The first event management strategy combination is an improvement to incident identification/verification and response associated with several complementary TSMO strategies including but not limited to:

- Providing Optimal ITS Device Deployment
- Optimize Data and Image Sharing
- Center to Center Interfaces
- Computer Aided Dispatch (CAD) Integration
- Maintenance and Emergency Response Agency Access to CCTV

The second event management strategy combination was the use of event-based dynamic shoulder lanes which activate in the vicinity of the incident location and provide increased capacity due to potential lane closures.

The data indicates significant travel time savings accrued for both improvements with the event-based dynamic shoulder lane exhibiting the largest reduction. In particular, the 2040 horizon year generates substantially more travel time benefits from incident management improvements; likely due to the fact that congestion is much worse in 2040 and therefore incremental improvements to traffic operations yield exponential improvements to network travel time.

Travel time savings were converted to present value benefits and costs, which were incorporated to generate the BCR and NPV as presented in **Table 6.47** below. As shown, the Incident Identification / Verification / Response Improvements yield a BCR of 1.5 and a NPV of approximately $5.9 million. The Event-Based Dynamic Shoulder Lanes yields a lower BCR of 3.6; however, the NPV is substantially higher at approximately $202.6 million.

Table 6.47: Benefit-Cost Ratio and NPV from Incident Management Improvements

SYSTEM IMPROVEMENT	BCR	NPV ($ MILLION)
Incident Identification / Verification / Response Improvements	1.6	$5.9
Event-Based Dynamic Shoulder Lane	3.6	$202.6

Section 7 – ALTERNATIVES RECOMMENDED FOR FURTHER EVALUATION

This section draws on the analysis in the previous sections to identify several alternatives, each comprised of a combination of improvement strategies, that are recommended for further analysis. The alternatives, summarized in **Figure 7.1**, were developed based on the anticipated traffic and safety benefits described in Section 6, potential environmental impacts, and estimated costs. The alternatives seek to capitalize on the complementary nature of the improvement strategies and provide a representative range of alternatives for detailed analysis during the environmental review process conducted under the National Environmental Policy Act (NEPA). The range of costs reflected in the alternatives also provide flexibility as INDOT and IDOT identify available funding for improvements in the corridor.

Figure 7.1: Alternatives

Lower Cost ($) → **Higher Cost ($)**

Alternative 1

Base Package
- Dynamic Shoulder Lanes
- Event Management (Light)
- Geometric Changes and Signing Enhancements

Alternative 2

Base Package + Ramp Metering
- Dynamic Shoulder Lanes
- Ramp Metering
- Event Management (Light)
- Geometric Changes and Signing Enhancements

Alternative 3

Base Package + Mainline Safety*
- Dynamic Shoulder Lanes
- Variable Speed Limits
- Lane Control
- Event Management (All)
- Queue Warning
- Geometric Changes and Signing Enhancements

Alternative 4

Base Package + Mainline Safety* + Ramp Metering
- Dynamic Shoulder Lanes
- Variable Speed Limits
- Ramp Metering
- Lane Control
- Event Management (All)
- Queue Warning
- Geometric Changes and Signing Enhancements

*Mainline Safety refers to those improvement strategies that focused primarily on safety and not traffic operations, which include variable speed limits, dynamic lane control, and queue warning.

The proposed contents of each alternative are provided in **Table 7.1** through **Table 7.4** below along with the associated implementation costs and the potential value, as presented in terms of the Benefit to Cost Ratio (BCR) and Net Present Value (NPV) for the analysis period between 2021 and 2040. All costs and benefits shown in the tables are presented in terms of 2021 present values. The key advantages and anticipated potential impacts have also been highlighted for each alternative. For comparative purposes, under the Strategy column or section in each table, the individual costs and potential benefits of each improvement strategy are provided along with the associated BCR and NPV. Under the Alternative section or column, refined costs (see **Appendix E** for source cost estimates) for each Alternative have been presented to address potential overlap or duplication of costs between the individual improvement strategies. Through this additional refinement, the combined costs shown under the Alternative section are lower than the sum of the individual costs for the improvement strategies listed under the Strategy section. The BCR and NPV have been recalculated for the Alternatives.

Following completion of the PEL Study, these alternatives will be assessed in further detail with regards to their performance, costs and potential environmental impacts, during the NEPA phase. That phase will also include additional coordination with INDOT, IDOT, and FHWA; resource and partner agencies; and stakeholders.

Table 7.1: Alternative 1 – Base Package

STRATEGY INCLUDED	STRATEGY			ALTERNATIVE		
	Cost [1] ($ Million)	Benefit ($ Million)	NPV BCR	Cost [1 2] ($ Million)	Benefit ($ Million)	NPV BCR
Dynamic Shoulder Lanes	($77.4)	$286.9	NPV = $209.5 BCR = 3.71	($97.8)	$452.1	NPV = **$354.3** BCR = **4.62**
Event Management (Light) * * (Applicable Complementary Strategies + TRIP and Hoosier Helpers)	($10.8)	$16.7	NPV = $5.9 BCR = 1.55			
Broadway Interchange and I-65 Interchange Modifications, and Signing Enhancements	($8.3)	$148.5	NPV = $140.2 BCR = 17.89			
Key Advantages						
▪ Significant improvement to traffic operations performance with dynamic shoulder lanes providing improved capacity to I-80/94 resulting in resolution of major recurrent bottlenecks. ▪ Improved event management through incident identification / response / mobilization is a cost-effective strategy that can utilize existing systems and processes. ▪ The Broadway interchange and I-65 interchange modifications and the resultant capacity improvements complement the TSMO strategies by resolving the downstream bottleneck near the I-65 eastbound exit ramp.						
Potential Impacts						
▪ N/A						

Notes:

1 Present value (PV) costs include capital costs and applicable annual maintenance and operations costs over the analysis period extending from 2021 to 2040.

2 Although the combined cost estimates have been refined (see Appendix E), due to the conceptual level of planning completed at this stage of the project, the Alternative costs may include some duplication of individual elements associated with multiple TSMO strategies.

Table 7.2: Alternative 2 – Base Package + Ramp Metering

STRATEGY INCLUDED	STRATEGY			ALTERNATIVE		
	Cost [1] ($ Million)	Benefit ($ Million)	NPV BCR	Cost [1 2] ($ Million)	Benefit ($ Million)	NPV BCR
Dynamic Shoulder Lanes Ramp Metering	($83.2)	$334.6	NPV = $251.4 BCR = 4.02	($104.1)	$499.8	NPV = **$395.7** BCR = **4.80**
Event Management (Light) * * (Applicable Complementary Strategies + TRIP and Hoosier Helpers)	($11.5)	$16.7	NPV = $5.2 BCR = 1.45			
Broadway Interchange and I-65 Interchange Modifications, and Signing Enhancements	($8.3)	$148.5	NPV = $140.2 BCR = 17.89			

Key Advantages

- Significant improvement to traffic operations performance with dynamic shoulder lanes providing improved capacity to I-80/94 resulting in resolution of major recurrent bottlenecks.
- Ramp metering limits the impact of high-volume entrance ramp locations from inducing turbulence to the I-80/94 mainline.
- Improved event management through incident identification / response / mobilization is a cost-effective strategy that can utilize existing systems and processes.
- The Broadway interchange and I-65 interchange modifications and the resultant capacity improvements complement the TSMO strategies by resolving the downstream bottleneck near the I-65 eastbound exit ramp.

Potential Impacts

- Increased diversion to municipal network as ramp meters deter short distance interchange-to-interchange trips on I-80/94.

Notes:

1 Present value (PV) costs include capital costs and applicable annual maintenance and operations costs over the analysis period extending from 2021 to 2040.

2 Although the combined cost estimates have been refined (see Appendix E), due to the conceptual level of planning completed at this stage of the project, the Alternative costs may include some duplication of individual elements associated with multiple TSMO strategies

Table 7.3: Alternative 3 - Base Package + Mainline Safety*

STRATEGY INCLUDED	STRATEGY			ALTERNATIVE		
	Cost [1] ($ Million)	Benefit ($ Million)	NPV BCR	Cost [1 2] ($ Million)	Benefit ($ Million)	NPV BCR
Dynamic Shoulder Lanes + Variable Speed Limits	($83.0)	Traffic Operations $354.6 VSL Safety $267.6	NPV = $539.2 BCR = 7.50	($161.3)	$1078.8	NPV = $917.5 BCR = 6.69
Event Management (All Strategies)	(11.5)	$296.7	NPV = $201.6 BCR = 3.12			
Lane Control	($83.6)	N/A				
Queue Warning	($14.7)	$11.4	NPV = ($3.3) BCR = 0.78			
Broadway Interchange and I-65 Interchange Modifications, and Signing Enhancements	($8.3)	$148.5	NPV = $140.2 BCR = 17.89			
Key Advantages						

Key Advantages

- Significant improvement to traffic operations performance with dynamic shoulder lanes providing improved capacity to I-80/94 resulting in resolution of major recurrent bottlenecks.
- Lane control can help reduce the potential for rear end crashes, which is the predominant crash type along the study corridor by providing drivers more time to respond and slow down.
- Variable speed limits provide significant improvement to corridor safety resulting in reduced crash frequency and severity.
- Queue warning provides improved traffic safety by reducing the potential for rear-end crashes or other secondary incidents and yielding a high BCR.
- Improved event management through incident identification / response / mobilization is a cost-effective strategy that can utilize existing systems and processes.
- The Broadway interchange and I-65 interchange modifications and the resultant capacity improvements complement the TSMO strategies by resolving the downstream bottleneck near the I-65 eastbound exit ramp.

Potential Impacts

- The proposed queue warning system may increase PDO crashes while reducing injury related crashes.

Notes:

1 Present value (PV) costs include capital costs and applicable annual maintenance and operations costs over the analysis period extending from 2021 to 2040.

2 Although the combined cost estimates have been refined (see Appendix E), due to the conceptual level of planning completed at this stage of the project, the Alternative costs may include some duplication of individual elements associated with multiple TSMO strategies.

*Mainline Safety refers to those improvement strategies that focused primarily on safety and not traffic operations, which include variable speed limits, dynamic lane control, and queue warning.

Table 7.4: Alternative 4 - Base Package + Mainline Safety* + Ramp Metering

STRATEGY INCLUDED	STRATEGY			ALTERNATIVE		
	Cost [1] ($ Million)	Benefit ($ Million)	NPV BCR	Cost [1 2] ($ Million)	Benefit ($ Million)	NPV BCR
Dynamic Shoulder Lanes + Variable Speed Limits + Ramp Metering	($86.5)	Traffic Operations $355.3 VSL Safety $267.6	NPV = $536.4 BCR = 7.20	($165.8)	$1079.5	NPV = **$913.7** BCR = **6.51**
Event Management (All Strategies)	(11.5)	$296.7	NPV = $201.6 BCR = 3.12			
Lane Control	($83.6)	N/A				
Queue Warning	($14.7)	$11.4	NPV = ($3.3) BCR = 0.78			
Broadway Interchange and I-65 Interchange Modifications, and Signing Enhancements	($8.3)	$148.5	NPV = $140.2 BCR = 17.89			

Key Advantages

- Significant improvement to traffic operations performance with dynamic shoulder lanes providing improved capacity to I-80/94 resulting in resolution of major recurrent bottlenecks.
- Ramp metering limits the impact of high-volume entrance ramp locations from inducing turbulence to the I-80/94 mainline.
- Variable speed limits provide significant improvement to corridor safety resulting in reduced crash frequency and severity.
- Lane control can help reduce the potential for rear end crashes, which is the predominant crash type along the study corridor by providing drivers more time to respond and slow down.
- Improved event management through incident identification / response / mobilization is a cost-effective strategy that can utilize existing systems and processes.
- The Broadway interchange and I-65 interchange modifications and the resultant capacity improvements complement the TSMO strategies by resolving the downstream bottleneck near the I-65 eastbound exit ramp.

Potential Impacts

- Increased diversion to municipal network as ramp meters deter short distance interchange-to-interchange trips on I-80/94.
- The proposed queue warning system may increase PDO crashes while reducing injury related crashes.

Notes:

1 Present value (PV) costs include capital costs and applicable annual maintenance and operations costs over the analysis period extending from 2021 to 2040.

2 Although the combined cost estimates have been refined (see Appendix E), due to the conceptual level of planning completed at this stage of the project, the Alternative costs may include some duplication of individual elements associated with multiple TSMO strategies.

*Mainline Safety refers to those improvement strategies that focused primarily on safety and not traffic operations, which include variable speed limits, dynamic lane control, and queue warning.