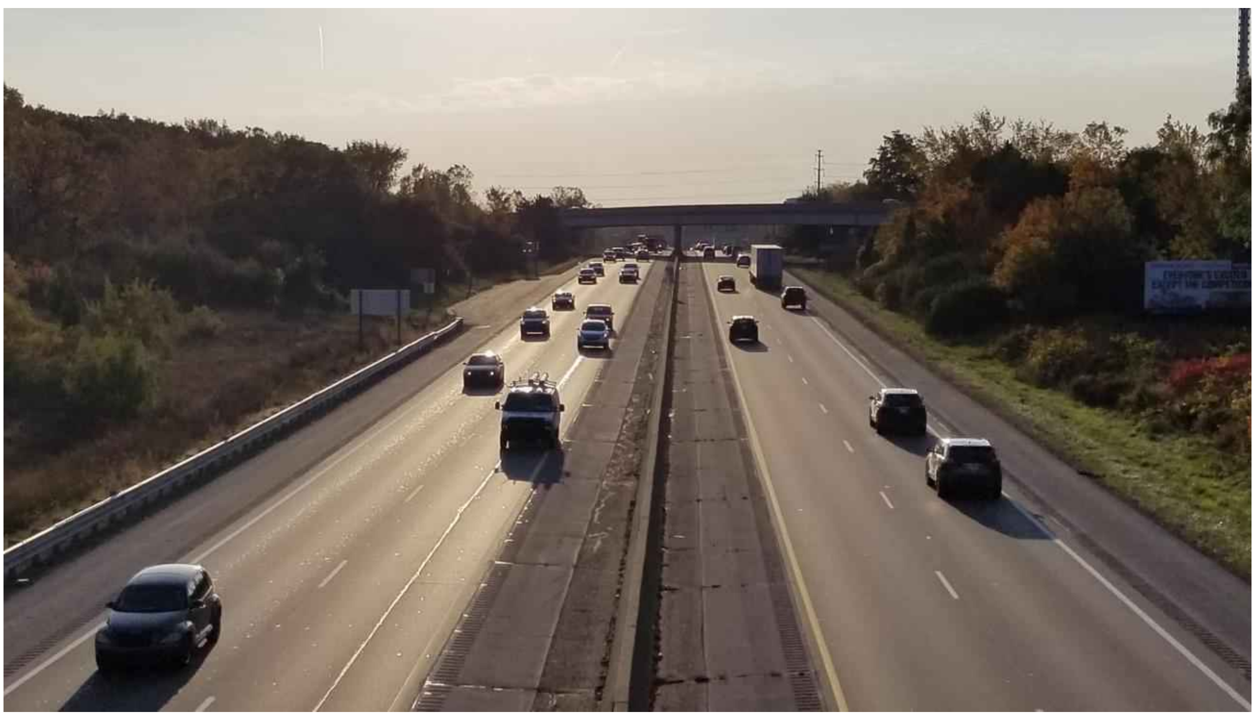
MICHIGAN DEPARTMENT OF TRANSPORTATION

# I-94 OPERATIONS STUDY:

## ANN ARBOR-SALINE ROAD TO US-23



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## ANN ARBOR-SALINE ROAD TO US-23

MICHIGAN DEPARTMENT OF TRANSPORTATION

FINAL REPORT (VERSION 2)

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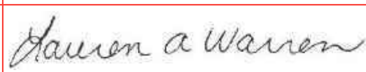
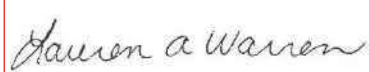
| Signature |  |  | | |

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# 1 INTRODUCTION

## 1.1 BACKGROUND & PURPOSE

I-94 between Ann Arbor-Saline Road and US-23 is a heavily used commuter and freight corridor of regional and national significance. Within this segment, I-94 is a four-lane freeway and widens to a six-lane freeway to the east of US-23 and to the west beyond M-14. Traffic operations and safety conditions along the I-94 corridor between M-14 and US-23 prompted a preliminary internal analysis by the Michigan Department of Transportation (MDOT) in 2016 to identify concepts for operational improvements. From that analysis, the section between Ann Arbor-Saline Road and US-23 was identified to have critical operational needs. MDOT analyzed an additional third travel lane in each direction, auxiliary lanes between interchanges, and a collector-distributor roadway at the US-23 system interchange. Issues identified with adding a third travel lane include ROW constraints that would likely require lane widths and shoulders narrower than current standards.

Subsequently, MDOT commissioned this study to provide a detailed review and enhanced analysis of the corridor improvements previously identified, as well as identify additional concepts to be analyzed and vetted through a public engagement process. This study's analysis included an in-depth review of geometrics, safety performance, traffic operations, and planning level construction cost estimates to identify preferred concepts that will be cost-effective and improve mobility, reliability, and safety along the corridor.

The initial study area from MDOT's 2016 study included I-94 from the Zeeb Road interchange to the US-12 interchange (Exit 181). The findings of this study indicated adequate capacity and operations west of the Ann Arbor-Saline Road interchange with forecasted traffic demand 20 years into the future. As a result, the study area for this more detailed study was truncated from immediately west of the Ann Arbor-Saline Road interchange to west of the US-12 interchange (Exit 181) and includes the service interchanges at Ann Arbor-Saline Road and State Street, and the system interchange at US-23 (see Figure 1).

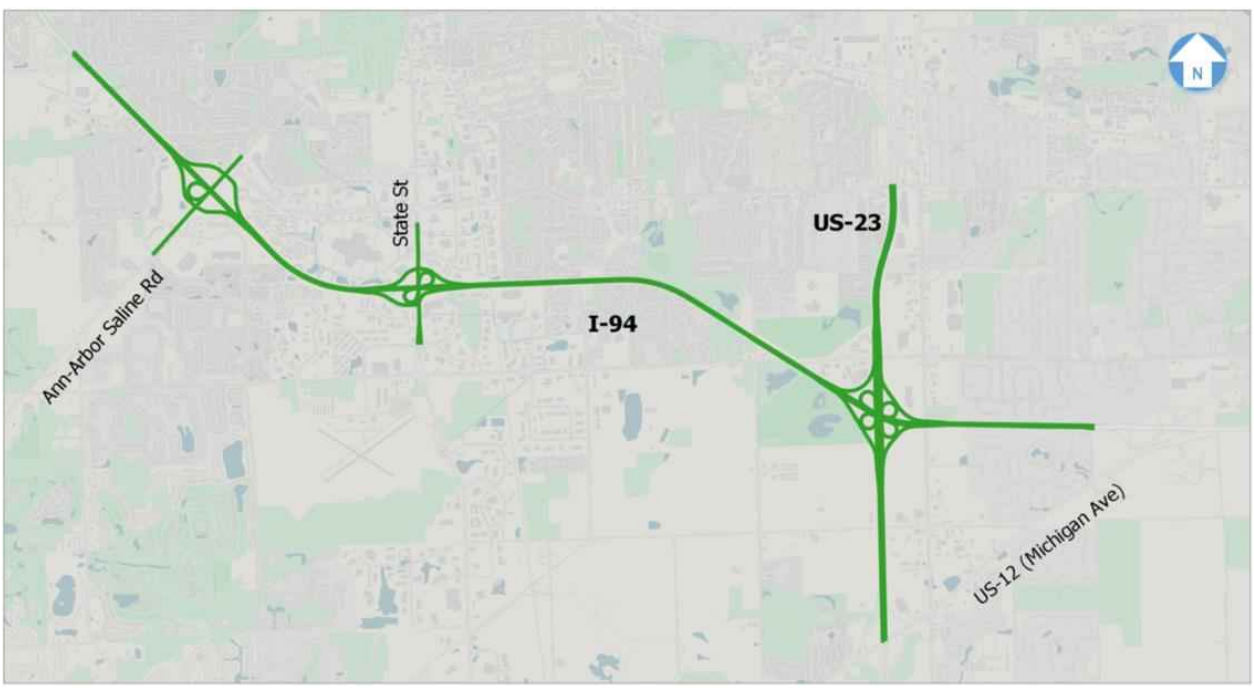



**Figure 1: Study Area**

To guide the study, a Local Stakeholder Group was formed at the onset and was composed of representatives from the agencies indicated in Figure 2.

**Local Stakeholder Group**

- Michigan Department of Transportation (MDOT)
- City of Ann Arbor
- Pittsfield Township
- Washtenaw Area Transportation Study (WATS)
- Washtenaw County Road Commission (WCRC)
- Federal Highway Administration (FHWA)

**Figure 2: Local Stakeholder Group**

The purpose of this study as solidified by the Local Stakeholder Group was as follows:

- Determine preferred concepts for a series of mobility, reliability, and safety improvements along the I-94 corridor from Ann Arbor-Saline Road to US-23.
- Develop concepts that optimally use the existing roadway footprint as much as possible to meet corridor performance needs and objectives in a process called **Performance-Based Practical Design**[1].
- Provide a roadmap for future study, design, and construction when funding becomes available.

The study itself was setup in three sequential phases. **Phase 1** focused on intensive data collection and assessment of existing conditions along the study corridor, including a summary of corridor deficiencies and needs that shaped the Purpose and Need Statement. **Phase 2** was the concept analysis phase where concepts were developed and analyzed at a high level with practical alternatives advanced for public feedback and preferred concepts identified for advancement. **Phase 3** provided additional refinement of the preferred concepts and the preparation of this study report to document the methods and findings of the study. Figure 3 illustrates the general workflow of the study.

[1] Performance-Based Practical Design (PBPD) can be articulated as modifying a traditional design approach to a "design up" approach where transportation decision makers exercise engineering judgment to build up the improvements from existing conditions to meet both project and system objectives. PBPD uses appropriate performance-analysis tools, considers both short and long term project and system goals while addressing project purpose and need. By exercising a greater level of discipline, agencies may eliminate nonessential project design elements resulting in lower cost and improved value. This approach enables States to deliver a greater number of projects than otherwise possible under their previous project development approaches. (FHWA, 2017).

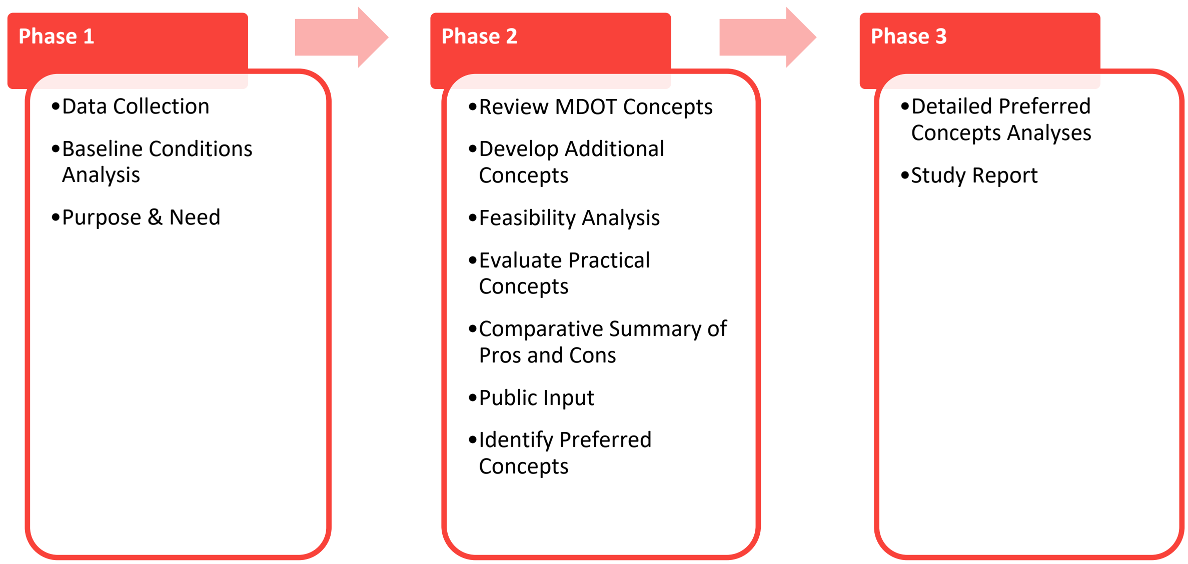



**Figure 3: Study Workflow**

The remainder of this report documents the study process and overall findings and is organized as follows:

- Baseline Conditions
- Purpose & Need
- Concepts Analysis
- Items for Further Consideration

# 2 BASELINE CONDITIONS

The assessment of Baseline Conditions is a critical step for any study as the direction of the project and subsequent recommendations are heavily steered by this initial assessment. The Baseline Conditions is a summary of the current conditions along the study corridor as it relates to geometrics, environmental features, safety, and operations. Essentially, this is a health check of the current state of the transportation system and documents the existing deficiencies. This information is then used to develop a Purpose and Need statement and subsequently shape the improvement concepts to be analyzed as part of the study process. The following details the Baseline Conditions assessment, including a summary of the data collected, corridor geometrics, environmental features, corridor safety, and corridor operations.

## 2.1 DATA COLLECTION

Several types of data were collected from various resources and agencies:

- **Survey**: Mobile LiDAR was obtained (2019) by the WSP team to capture topographic information for the hard surface areas which were then combined with previous aerial LiDAR data to provide complete coverage of the overall project area. Bottom of beam elevations for all structures was also collected within the study corridor.
- **Road and Bridge Condition Reports**: MDOT provided existing road and bridge condition reports for the study area.
- **As-Built Plans**: MDOT provided As-Built plans for the study area.
- **Traffic Data:** Traffic count data and vehicle classification data was obtained primarily from MDOT (2018) along the study corridor and supplemented with some interchange turning-movement counts obtained by WSP (2019). Speed and congestion information was obtained by WSP through the Regional Integrated Transportation Information System (RITIS) interface, which summarizes current and historical vehicle probe data along the corridor. The data was screened and verified as representative of typical operating conditions along the corridor as detailed in Appendix B.
- **Traffic Signal Timings**: Traffic signal timing data was obtained for the signalized interchange ramp terminals and immediately adjacent signalized intersections within the study area from MDOT, the City of Ann Arbor, and field review by WSP.
- **Travel Demand Forecasting**: Traffic forecasts for the future year of 2045 were obtained by MDOT from the regional travel demand model maintained by the Southeast Michigan Council of Governments (SEMCOG). It was agreed by MDOT, the Washtenaw Area Transportation Study (WATS), and SEMCOG that using the SEMCOG travel demand model made the most sense for this project given the larger regional analysis area that the I-94 corridor draws from.
- **Safety data**: WSP obtained the five most recent years of crash data along the study corridor that were available at the onset of this study (2013-2017). This data was obtained from the Michigan Traffic Crash Facts database (www.michigantrafficcrashfacts.org) which is maintained by the University of Michigan in coordination with the Michigan Office of Highway Safety Planning.
- **Environmental Features**: Key land use and environmental information was obtained from several resources, including the Michigan Department of Environmental Quality (MDEQ) Environmental Mapper and the web mapping applications available through the Washtenaw County Map Gallery and City of Ann Arbor Data Catalog. This data was reviewed for general land use, hazardous materials, wellhead protection areas, floodplains, floodways, creeksheds, watersheds, wetlands, streams, parks, trails, recreational facilities, and historic resources.
- **Previous Studies and Planning Documents**: Relevant studies were obtained from the various agencies including the previous MDOT internal operational analysis of the project corridor (2016), the *South State*

*Street Corridor Transportation Study* (2017), the *City of Ann Arbor's Transportation Master Plan*, and *Pittsfield Township's Master Plan*.

## 2.2 GEOMETRICS

### TYPICAL SECTION

The study corridor was originally constructed in the 1950s from east of Ann Arbor - Saline Road to west of Michigan Ave. Since original construction, a median barrier was constructed in 1975 and some bridge rehabilitation occurred throughout the 1970s to 1980s. The corridor and has not received any significant geometric improvements since the 1950s.

I-94 consists primarily of a four-lane freeway (two 12-foot eastbound lanes and two 12-foot westbound lanes) with a concrete median barrier. The inside shoulder is 11.84 feet paved and the outside shoulder is 9 feet paved with an additional 1 foot to 3 feet of aggregate on the outside (see Figure 4). The section between US-23 and Michigan Avenue has an additional 12-foot lane auxiliary lane with a 10 foot outside shoulder.

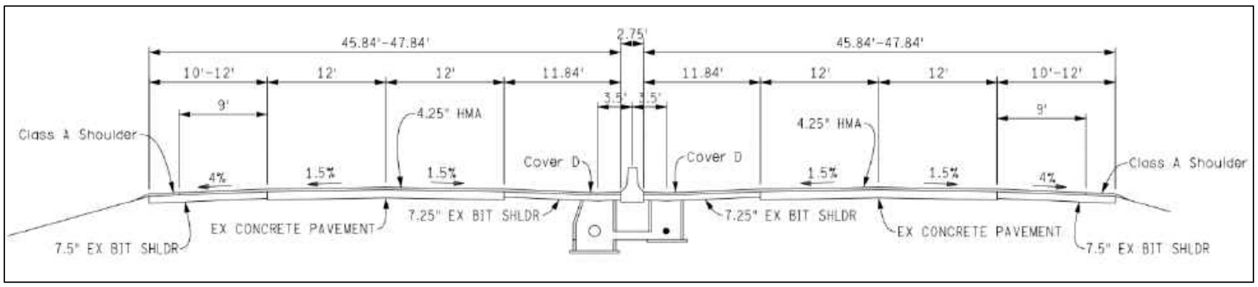



**Figure 4: Existing Typical Section - I-94**

### INTERCHANGES AND CROSSINGS

There are three interchanges within the study corridor:

- Ann Arbor - Saline Rd (service)
- State Street (service)
- US-23 (system)

The study corridor contains four local cross roads, one railroad and two pedestrian crossings:

- Ann Arbor Railroad (primary operating railroad and subsidiary to WATCO Companies)
- Stone School Road
- Stone School (pedestrian)
- Plainview Court (pedestrian)
- Platt Road
- E. Ellsworth Road
- Carpenter Road

There is a 12-foot collector-distributor (CD) road with an inside valley gutter and 6-foot paved and 3-foot aggregate outside shoulder on eastbound I-94 at the US-23 cloverleaf system interchange. This CD road is separated from eastbound I-94 by a median concrete barrier.

## HORIZONTAL ALIGNMENT

**Curves:** Existing geometric conditions were evaluated based on current AASHTO and MDOT geometric standards. I-94 within the study area consists of three horizontal curves (see Figure 5) ranging from 2,870 feet to 3,860 feet in radii and superelevation ranging from 3.7% to 5.3%. None of the horizontal curves superelevation meet current standards at 70 mph design speed using MDOT Standard Plan R-107-H. However, using AASHTO Straight Line Method Superelevation, curves No. 2 and 3 meet minimum superelevation standards at a 75 mph design speed. Horizontal stopping sight distance at curve No. 3 shown below is sub-standard due to the tight horizontal curves adjacent to the pier of the US-23 structure. On eastbound I-94, the median pier obstructs the driver's line of sight necessary to achieve the stopping sight distance at a 75mph design speed while the tail span pier is the line of sight obstruction for westbound I-94 traffic. Table 1 provides a summary of the horizontal curve data for these three locations.

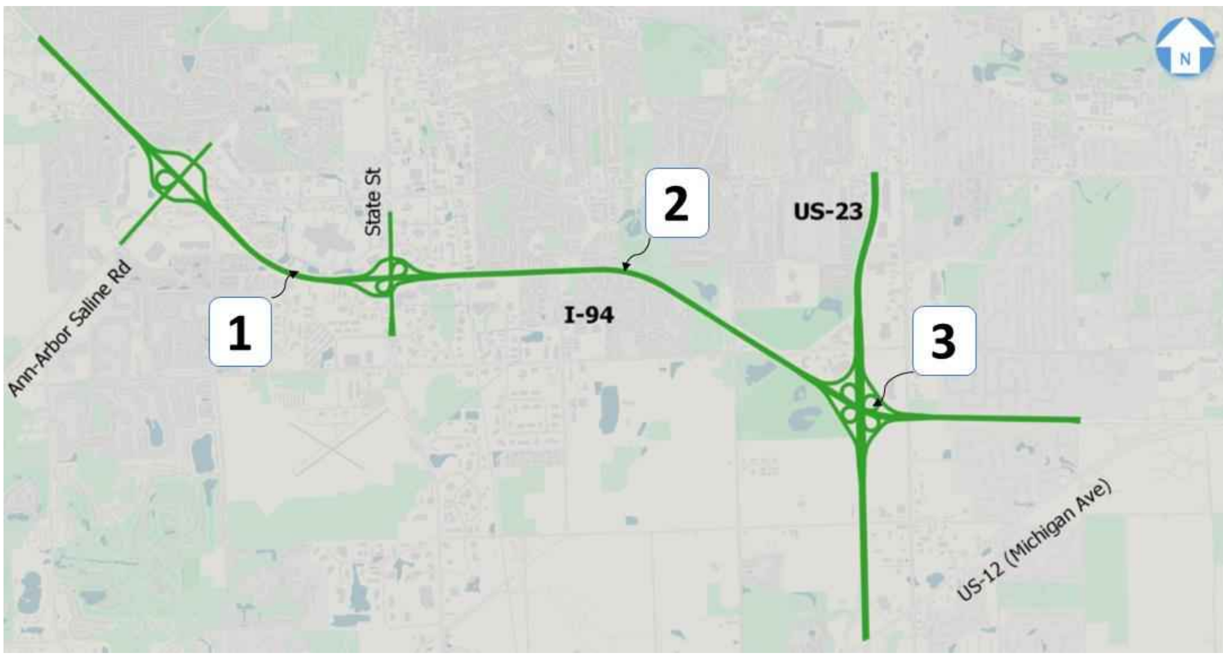



Figure 5: I-94 Horizontal Curve Locations

Table 1: I-94 Horizontal Curve Data

| Horizontal Curve (WB to EB) | Existing Radius | Current Design Speed Met | Current SSD Criteria met | Existing Rate of SE | Current MDOT R-107 Standard SE | Current AASHTO Straight Line Standard SE |
|---|---|---|---|---|---|---|
| **1** | 3775' | 75mph + | N/A | 3.7% | 5.6% | 4.1% |
| **2** | 3860' | 75mph + | N/A | 4.0% | 5.5% | 4.0% |
| **3** | 2870' | 75mph + | No | 5.3% | 6.5% | 5.3% |

**Ramps:** The entrance and exit ramps at the existing State Street interchange (Parclo-A-4-Quad interchange), Ann Arbor-Saline interchange (diamond interchange with a loop ramp) and US-23 interchange (cloverleaf) do not meet current MDOT geometric standards. A summary of the sub-standard elements at these interchanges is shown in Table 2.

**Table 2: Existing Sub-Standard Interchange Ramp Elements**

| Interchange | | Design Speed/Radius | Accel/Decel Lane | Taper Length | Shoulder Width |
|---|---|---|---|---|---|
| **Ann Arbor-Saline Rd** | WB I-94 to AA Saline | | | | |
| | NB AA Saline to EB I-94 | | × | × | |
| | EB I-94 to AA Saline | | | | |
| | AA Saline to WB I-94 | | | | |
| | SB AA Saline to EB I-94 | × | × | × | × |
| **State St** | WB I-94 to State | | | | |
| | NB State to EB I-94 | | | × | |
| | EB I-94 to State | | | | |
| | SB State to WB I-94 | | | × | |
| | NB State to WB I-94 | × | × | × | |
| | SB State to EB I-94 | × | × | × | |
| **US-23** | WB I-94 to NB US-23 | | | | × |
| | NB US-23 to EB I-94 | | | | × |
| | EB I-94 to SB US-23 | | | | × |
| | SB US-23 to WB I-94 | | × | × | × |
| | NB US-23 to WB I-94 | × | × | | × |
| | EB I-94 to NB US-23 | × | × | | × |
| | SB US-23 to EB I-94 | × | × | | × |
| | WB I-94 to SB US-23 | × | × | | × |

## VERTICAL ALIGNMENT

The existing vertical conditions were evaluated based on current AASHTO and MDOT vertical standards. The profile grades range from approximately 0.10% to 2.90% in the sag and crest conditions within the survey limit between Ann Arbor-Saline and US-23 interchange. The k value and stopping sight distance at the vertical curve over the Railroad just east of State Street only meets current standards at 60 mph design speed. The rest of the vertical curves meet current standards at 70 mph design speed.

The elevations have a range of approximately 120 feet from the highest crest to the lowest sag vertical curve for the I-94 study corridor. The existing vertical clearance values for the overpass bridges are provided in Table 3.

**Table 3: Existing Structure Data along I-94 Study Corridor**

| Structure ID | FACILITY CARRIED | LANES ON BRIDGE<br>LANES UNDER BRIDGE | DECK WIDTH (feet)<br>HORIZONTAL CLEARANCE (feet) | VERTICAL<br>CLEARANCE | YEAR BUILT<br>RECONSTRUCTED |
|---|---|---|---|---|---|
| S01 of 81062 | I-94 over Jackson | 4 | 93.5' | 14'-2" L | 1956 |
| | | 4 | 59.7' R | 14'-6" R | |
| S02 of 81062 | Liberty Road** | 2 | 27.89' | 14'-8" L | 1956 |
| | | 4 | 52.8' L 52.8' R | 14'-8" R | |
| S03 of 81062 | Scio Church Rd** | 2 | 28.22" | 14'-6" L | 1956 |
| | | 4 | 50.5' L 50.5' R | 14'-8" R | |
| C01 of 81062 | I-94 (Ann Arbor Saline) | 6 | na | na | 1900 |
| S04 of 81062 | Ann Arbor-Saline Rd | 2 | 87.93' | 16'-7" L | 1974 |
| | | 5 | 75.5' L 75.5' R | 16'-0" R | |
| C02 of 81062 | I-94 (0.3 mile W of State) | 4 | na | na | 1900 |
| S05 of 81062 | State Rd | 6 | 117.78' | 16'-11" L | 1972 |
| | | 6 | 75.8' L 75.8' R | 17'-0" R | |
| C03 of 81062 | I-94 (EB Off Ramp State) | 4 | na | na | 1900 |
| R01 of 81062 | I-94 over AA Railroad | 4 | 94.49' | TBD | 1954 |
| | | | | | 1975 |
| S06 of 81062 | Stone School Rd** | 2 | 25.92' | 14'-7" L | 1954 |
| | | 4 | 45.3' L 45.3' R | 14' - 7" R | |
| P01 of 81062 | Stone School Ped | 4 | 99.7' L 99.7' R | 16' - 19" L | 1975 |
| | | | | 16' - 8" R | |
| C04 of 81062 | I-94 (Rayer & Grance Drain) 0.1 mile E of Stone School | 4 | na | na | 1900 |
| P02 of 81062 | Planview Ct Ped | 4 | 70.9' R | 16'-9" L | 1975 |
| | | | | 16'-7" R | |
| S07 of 81062 | Platt Rd | 5 | 63.98' | 16'-7" L | 1998 |
| | | 4 | 50.9' L 50.9' R | 16'-9" R | |
| S13 of 81062 | Ellsworth Rd | 4 | 63.98' | 16'-11" L | 1995 |
| | | 4 | 83' L 83' R | 17'-6" R | |
| S08-1 of 81062 | US-23 NB | 4 | 78.9' | 18'-1" L | 1962 |
| | | 7 | 51.8' L 50.2' R | 17'-6" R | 2005 |
| S08-2 of 81062 | US-23 SB RAMP | 4 | 58.4' | 16'-10" L | 1962 |
| | | 7 | 51.8' L 50.2' R | 16'-6" R | |
| S09 of 81062 | Carpenter Rd | 5 | 63.98' | 15'-9" L | 1995 |
| | | 7 | 85' L 80.7' R | 16'-2" R | |

### UTILITIES

A preliminary field investigation was performed to identify locations of overhead electrical lines. Locations include:

- 2000’ west of State St
- 50’ west of RR tracks
- 300’ east of Stone School
- 600; east of Ellsworth
- 400’ east of Carpenter

### DRAINAGE

The existing freeway throughout the study area is comprised of an open roadway section where median drainage is collected and conveyed to the roadside ditches with storm sewer. There are also four culverts within the project limits. See Table 3 for culvert information.

- C01 of 81062 – I-94 over No Name (@ Ann Arbor Saline Rd)
- C02 of 81062 -- I-94 over No Name (0.3 Mile west of State St)
- C03 of 81062 -- I-94 over No Name (EB Off Ramp State Rd)
- C04 of 81062 – I-94 over Rayer & Grance Drain (0.1 mile E of Stone School Rd)

## 2.3 ENVIRONMENTAL FEATURES

A diverse mix of social, cultural and natural features are found within the study area as shown in Figure 6. The limits of the City of Ann Arbor adjoin the study corridor, extending south of I-94 to Ellsworth Road between State Street and US-23. Land use adjacent the I-94 and US-23 corridors is extensively developed featuring a mixture of uses. Along the western portion of the I-94 corridor, predominant land use includes commercial, office, research and industrial and multi-family development with the Briarwood Mall retail center located north and west of the State Street interchange. This is contrasted by the presence of single-family residential areas and public lands found extensively along the eastern portion of the I-94 corridor and the US-23 corridor.

Several parkland and natural areas tracts are prominent in the eastern part of the study area including Mary Beth Doyle Park, Southeast Area Park, Swift Run Marsh, the Scarlett-Mitchell Nature Area, and the Lloyd and Mabel Johnson Preserve all adjoining I-94, while Turnberry Park is located immediately west of US-23. Ownership varies though the City of Ann Arbor administers most of the facilities along with the Washtenaw County Water Resources Commission and the Ann Arbor Public Schools.

Natural features are also present including Malletts Creek, a tributary of the Huron River. This water course meanders through the western half of the study area with scattered wetland areas and floodplain, crossing I-94 twice as it passes through a portion of the State Street interchange. Further east, Swift Run also crosses I-94 as both streams flow northeast towards the Huron River. The Washtenaw County Water Resources Commission is responsible for Malletts Creek as it is a designated drain.

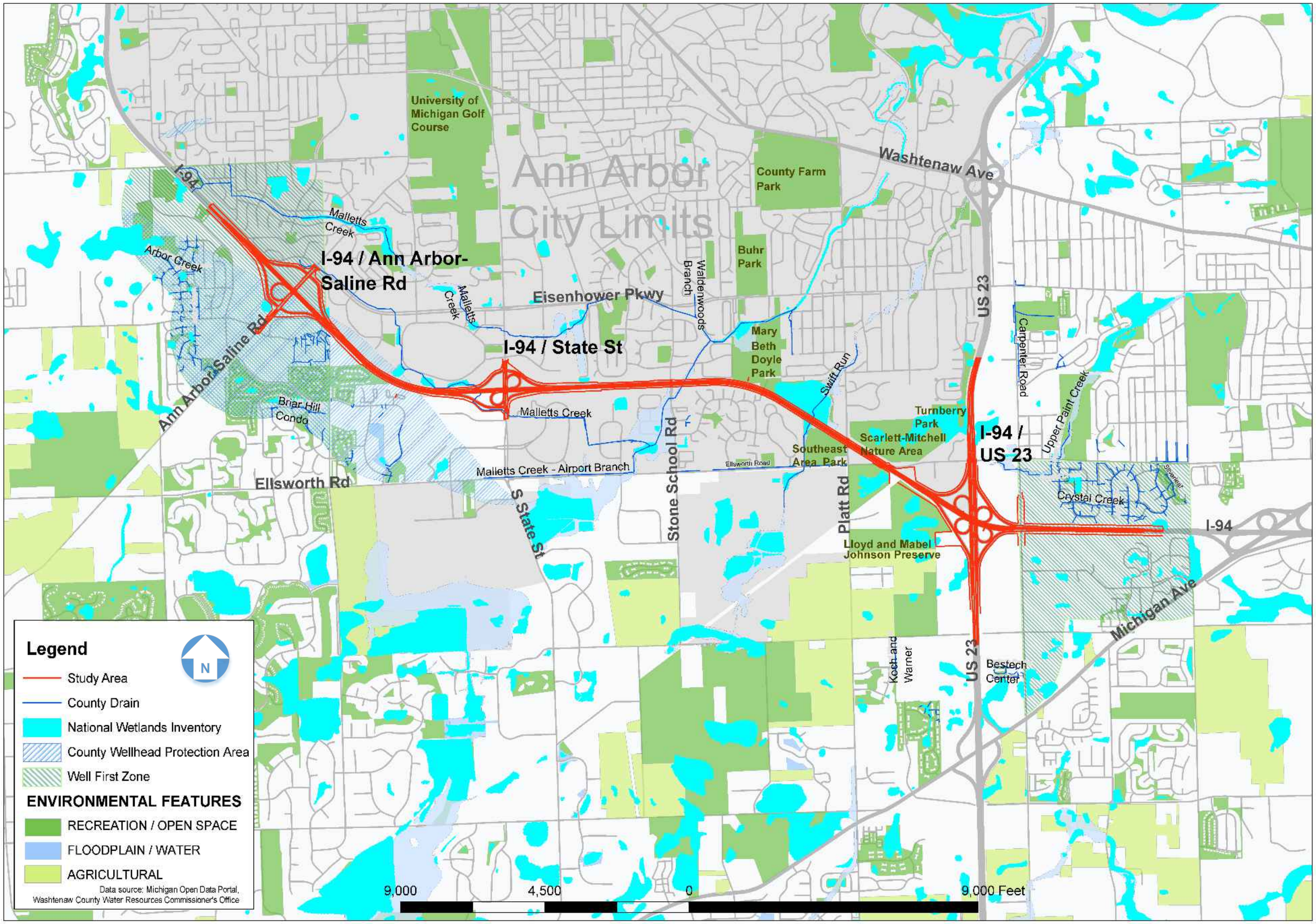



**Figure 6: Environmental Features Mapping**

## 2.4 SAFETY

To analyze the safety impacts of current and future reconstruction alternatives of I-94 between Ann Arbor-Saline Rd and US-23, the most recent 5-years of crash data (January 1, 2013 through December 31, 2017) was obtained from Michigan Traffic Crash Facts (MTCF). The following is a summary of the crash analysis with the detailed crash analysis provided in Appendix A. The crash analysis area, as highlighted in Figure 7, encompasses mainline I-94 from Scio Church Road on the western end to just east of the US-23 interchange and the interchanges and ramps of Ann Arbor-Saline Road, State Street, and US-23. Additionally, segments of US-23 north to the Packard Street overpass and south past the Morgan Road were included. The following surface street intersections were also reviewed:

- Ann Arbor-Saline Road at Eisenhower Parkway
- Ann Arbor-Saline Road at Waters Road
- State Street at Eisenhower Parkway
- State Street at Victors Way/Hilton Boulevard
- State Street at Airport/Research Boulevard

A total of 2,955 crashes (excludes 70 animal related crashes) occurred during the five years reviewed. As shown in Table 4, eight (8) of the total crashes within the full influence area resulted in a fatality while 34 resulted in a serious injury (Type A) and 133 in a minor injury (Type B). Six of the fatalities occurred on the I-94 mainline, with three (3) in the eastbound lanes and three (3) in the westbound lanes. Additionally, two of those fatalities were specifically related to traffic congestion.

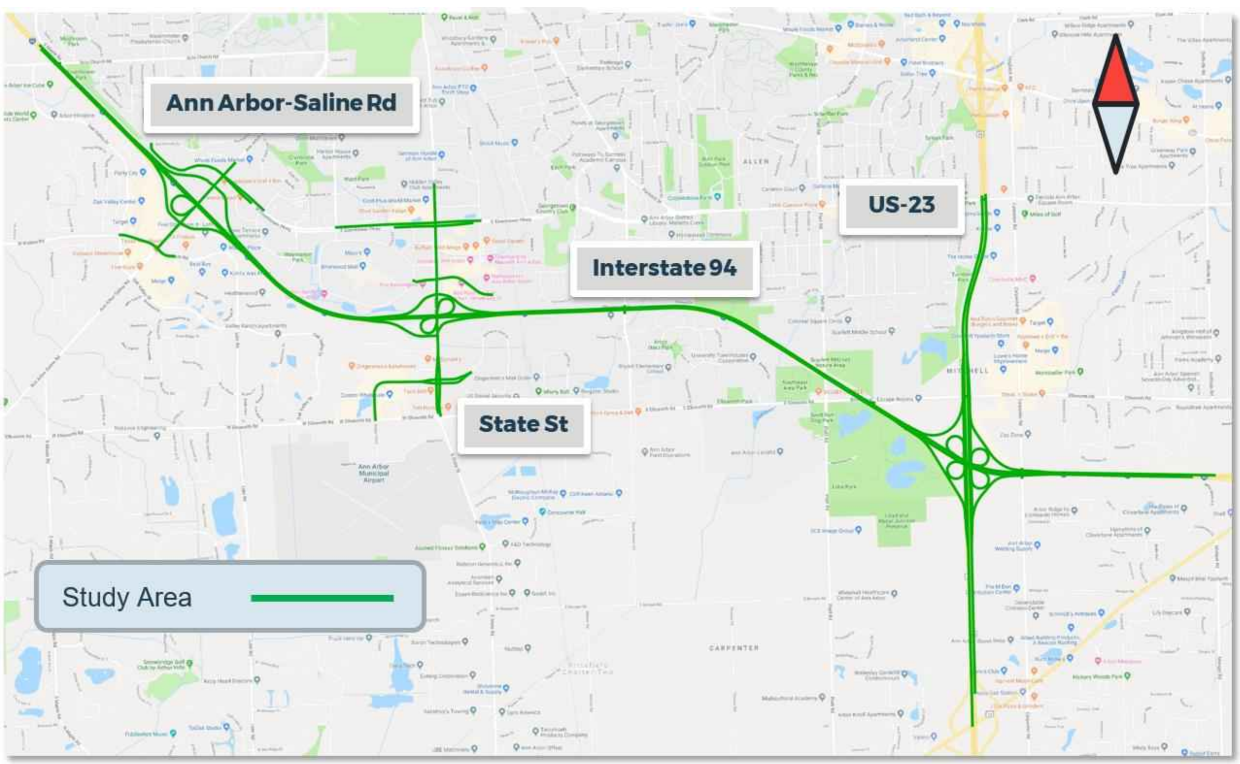



**Figure 7: Crash Study Area**

**Table 4: Injury Crash Type by Year (2013-2017)**

| I-94 Influence Area | 2013 | 2014 | 2015 | 2016 | 2017 | Total Injury crash type |
|---|---|---|---|---|---|---|
| **Fatal (K)** | 2 | 0 | 2 | 2 | 2 | **8** |
| **Serious Injury (A)** | 7 | 11 | 0 | 6 | 10 | **34** |
| **Minor Injury (B)** | 22 | 20 | 23 | 40 | 28 | **133** |
| **Possible Injury (C)** | 81 | 71 | 57 | 86 | 76 | **371** |
| **No Injury (PDO)** | 444 | 521 | 435 | 537 | 472 | **2,409** |
| **Total Annual Crashes** | **562** | **636** | **538** | **685** | **604** | **2,955** |

Figure 8 provides the proportion of the top three most predominant crash types by facility category for crashes of all severities with all other crash types grouped as "other". These typically included rear end, single motor vehicle, and sideswipe same direction for interstate facilities while surface streets and intersections experienced rear end, sideswipe same direction, and angle crashes more frequently. These crash types tended to remain the most predominant when considering only fatal and serious injuries, particularly for those along the interstate facilities.

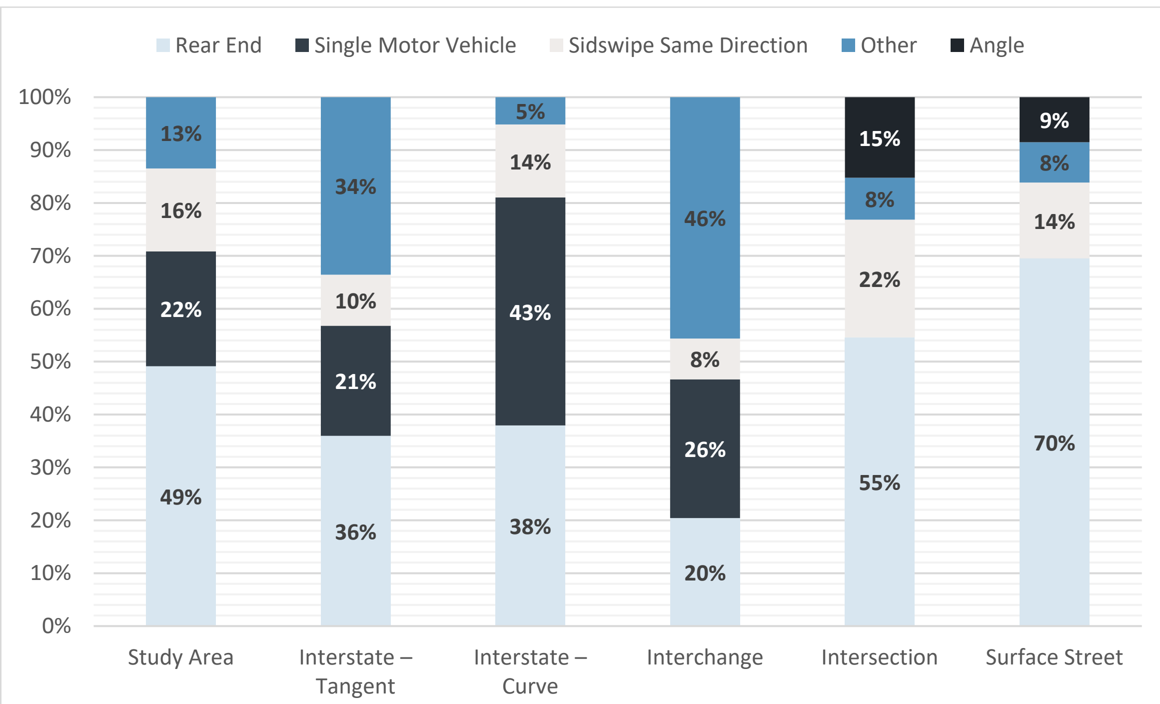



**Figure 8: Predominant Crash Type (All Severities 2013-2017)**

Crashes occurring along I-94 were reviewed to consider broad trends regarding potential contributing factors, environmental conditions, and driver behavior. As shown in Figure 9, most crashes occurred under dry, clear conditions along the interstate facilities, thus environmental conditions do not appear to play a significant role in most crash trends. Crashes of all severities along the I-94 mainline tended to peak during the winter months, with fatal and serious injury crashes peaking during the spring and summer months.

**Study Area**

| All Severities / **Fatal & Serious Injury** |
|---|
| 2,955 / **42** |

- **Interstate**: 1,847 / **38**; 63% / **90%**
- **Surface Streets**: 1,068 / **4**; 36% / **10%**

| | | Mainline | Interchange | Segments | Intersections |
|---|---|---|---|---|---|
| Facility Type | | 1,507 / **31** | 340 / **7** | 523 / **1** | 547 / **3** |
| | | 82% / **82%** | 18% / **18%** | 49% / **25%** | 51% / **75%** |
| Lighting | Dark - Unlighted | 333 / **7** | 61 / **1** | 11 / **0** | 9 / **1** |
| | Dawn / Dusk | 129 / **4** | 26 / **2** | 19 / **0** | 17 / **0** |
| | Dark - Lighted | 16 / **0** | 10 / **0** | 84 / **0** | 85 / **0** |
| | Daylight | 1026 / **20** | 243 / **4** | 422 / **1** | 413 / **2** |
| Road Condition | Ice / Slush | 140 / **1** | 24 / **1** | 19 / **0** | 24 / **0** |
| | Snow | 128 / **1** | 17 / **0** | 20 / **0** | 43 / **0** |
| | Wet | 207 / **4** | 102 / **1** | 90 / **1** | 88 / **1** |
| | Dry | 1026 / **24** | 194 / **5** | 407 / **0** | 366 / **2** |
| Citation* | Failure to Stop in Assured Clear Distance | 452 / **3** | 63 / **1** | 333 / **1** | 234 / **1** |
| | Speeding Too Fast for Conditions | 301 / **6** | 113 / **2** | 28 / **0** | 8 / **0** |
| | Failed to Yield | 29 / **0** | 16 / **0** | 79 / **0** | 109 / **1** |

*Citation statistics obtained from Michigan Department of Transportation one-line crash data. Numbers may differ slightly from Michigan Traffic Crash Facts.

**Figure 9: Crash Contributing Factors (2013-2017)**

Based on the predominant crash types historically reported along the study corridor, along with the relatively low trends in environmental contributing factors, a significant portion of crashes are a result of traffic congestion along the corridor. The second contributing factor is driver behavior and response to changes in traffic flow. These incidents are likely due to merging or lane changes as drivers enter and exit the freeway, as well as congestion related queueing during peak hours or significant events. Approximately fifteen percent (15%) of crashes of all severities along I-94 and US-23 were cited as being related to back up from regular congestion, including five fatal and/or serious injury crashes. The location of these clusters of crashes are highlighted in Figure 10.

Rear-end and sideswipe crashes on the freeway are concentrated at the State Street interchange and at the US-23 system interchange (primarily occurring along the westbound lanes at the US-23 interchange, likely due to slowed traffic as vehicles weave between the loop ramps under the US-23 overpass and congestion spilling back from the westbound I-94 to northbound US-23 exit ramp.

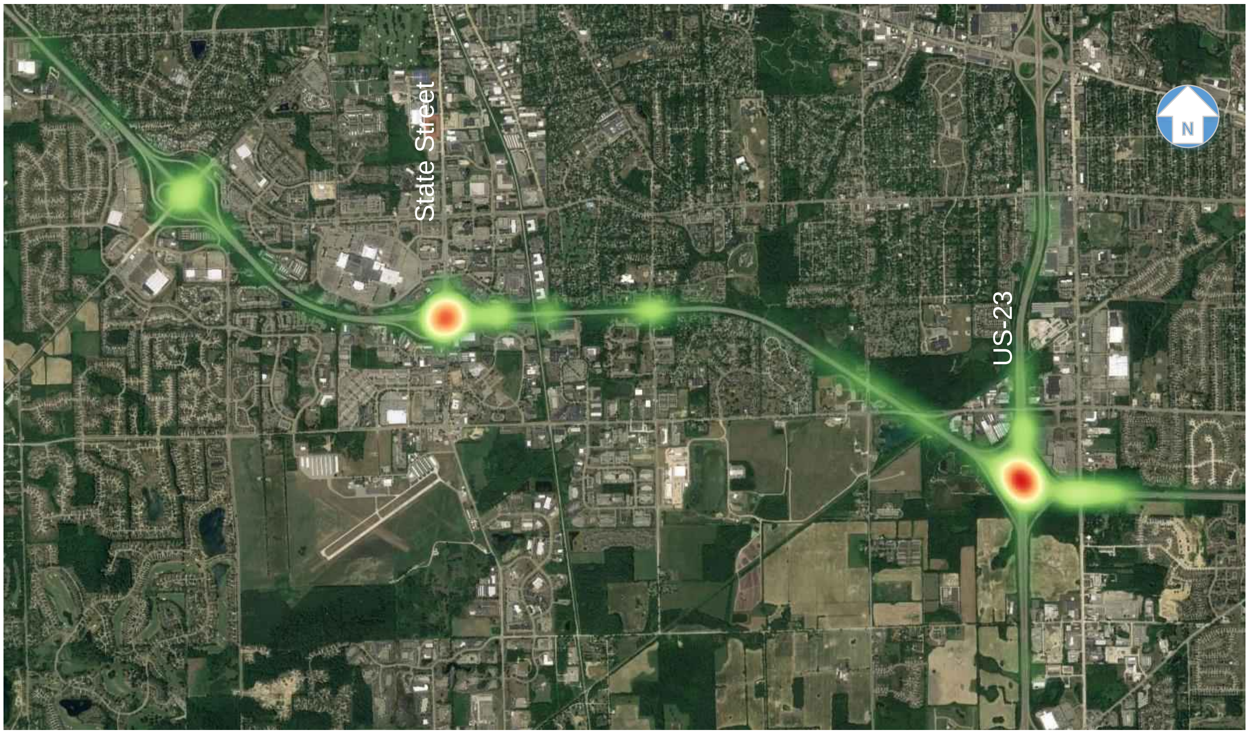



Figure 10: Hotspot Map - Freeway Crashes

## SUMMARY

Over the five-year study period, crashes of all severities in the defined influence area have generally increased despite minor yearly fluctuations. Based on a review of historic crash data, many of these crashes can be attributed to congestion related crashes (rear-end and sideswipe same direction). Specific hotspots that stood out were as follows:

- WB I-94 in advance of the exit ramp to NB US-23: a significant portion of rear-end and sideswipe crashes occur in this area likely due to the congestion from the regular capacity bottleneck at this location.
- WB I-94 at US-23 loop ramps: Heavy congestion and high weaving volumes between the two US-23 loop ramps along WB I-94 in this area are the most significant contributing factors to this hotspot.
- WB I-94 at Stone School Road: There were three A-severity crashes occurring underneath the bridge of Stone School Road all on the westbound side of I-94.

- I-94 at State Street: a significant portion of rear-end and sideswipe crashes occur along I-94 at this interchange due to regular congestion and heavy volume interactions between mainline I-94 and the State Street ramps.
- State Street between I-94 ramp terminals: A significant amount of sideswipe crashes occur along State Street on the bridge over I-94. Likely cause is the left-turn traffic from the ramp terminals merging with free-flow State Street traffic.

## 2.5 OPERATIONS

I-94 between Ann Arbor-Saline Road and US-23 is a heavily used commuter and freight corridor of regional significance. The segment between State Street and US-23 is in the top 10 of the highest volume two-lane freeway segments in Michigan with an average annual daily traffic count (AADT) of approximately 94,000 (2019). The freeway carries high directional volumes during peak periods, resulting in frequent periods of congestion during the AM and PM commuter rush. This not only impacts I-94, but also regularly impacts operations along US-23 at the system interchange and is a major contributor to user-delay and poor travel time reliability in the region. Outside of these peak times, operations are generally free flow unless there is an incident or a University of Michigan football game.

Figure 11 and Figure 12 illustrate the typical congestion experienced along I-94 during the AM and PM commuter rush periods. Figure 13 illustrates the AM and PM peak hour volumes for the 2018 Base Conditions (7:00 AM – 8:00 AM; 4:30 PM – 5:30 PM). Key operational issues during these time periods are as follows:

*AM Commuter Rush Period*

- Westbound I-94 travel speeds are typically slower between State Street and US-23 which frequently results in congestion due to the high-volume exit ramp traffic to State Street (approximately 44% of the traffic on westbound I-94 west of US-23 exits at State Street during the AM peak). This leads to heavy lane imbalance in this section with much of the traffic trying to get over into the right lane to exit at State Street.
- Severe congestion forms along westbound I-94 that spills back from the US-23 system interchange for up to 6 miles to the east along I-94 due to the high-volume westbound exit ramp traffic to US-23. Specifically, the westbound I-94 to northbound US-23 movement is a known bottleneck during this time period due to the limited capacity of this single lane exit ramp merging with the northbound US-23 collector-distributor traffic and then merging again with the northbound mainline US-23 traffic.
- This westbound I-94 congestion typically lasts for 2.5 to 3 hours on a normal weekday.

*PM Commuter Rush Period*

- Eastbound I-94 typically experiences heavy congestion between the Ann Arbor-Saline interchange and the State Street interchange due to high-volume entrance ramps merging with eastbound I-94 at the State Street interchange.
- There is not enough capacity for the State Street merging entrance ramp volumes during this time period, which results in queuing from the State Street interchange that spills back to the Ann Arbor-Saline interchange as well as queueing that spills back from eastbound I-94 onto State Street, impacting surface street operations.
- This congestion typically lasts for 2.5 to 3 hours on a normal weekday.

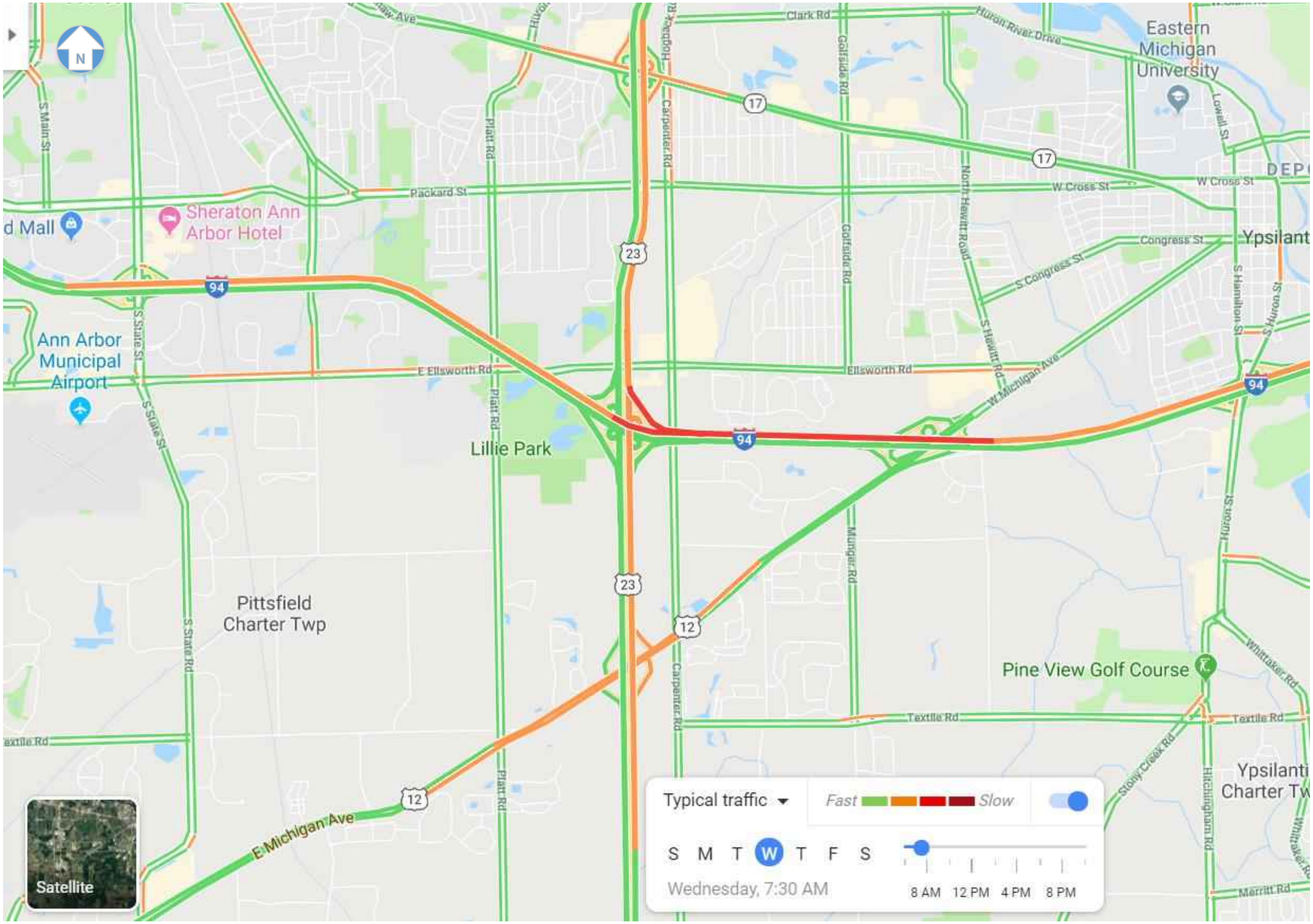



**Figure 11: Typical Congestion AM Commuter Rush (Google)**

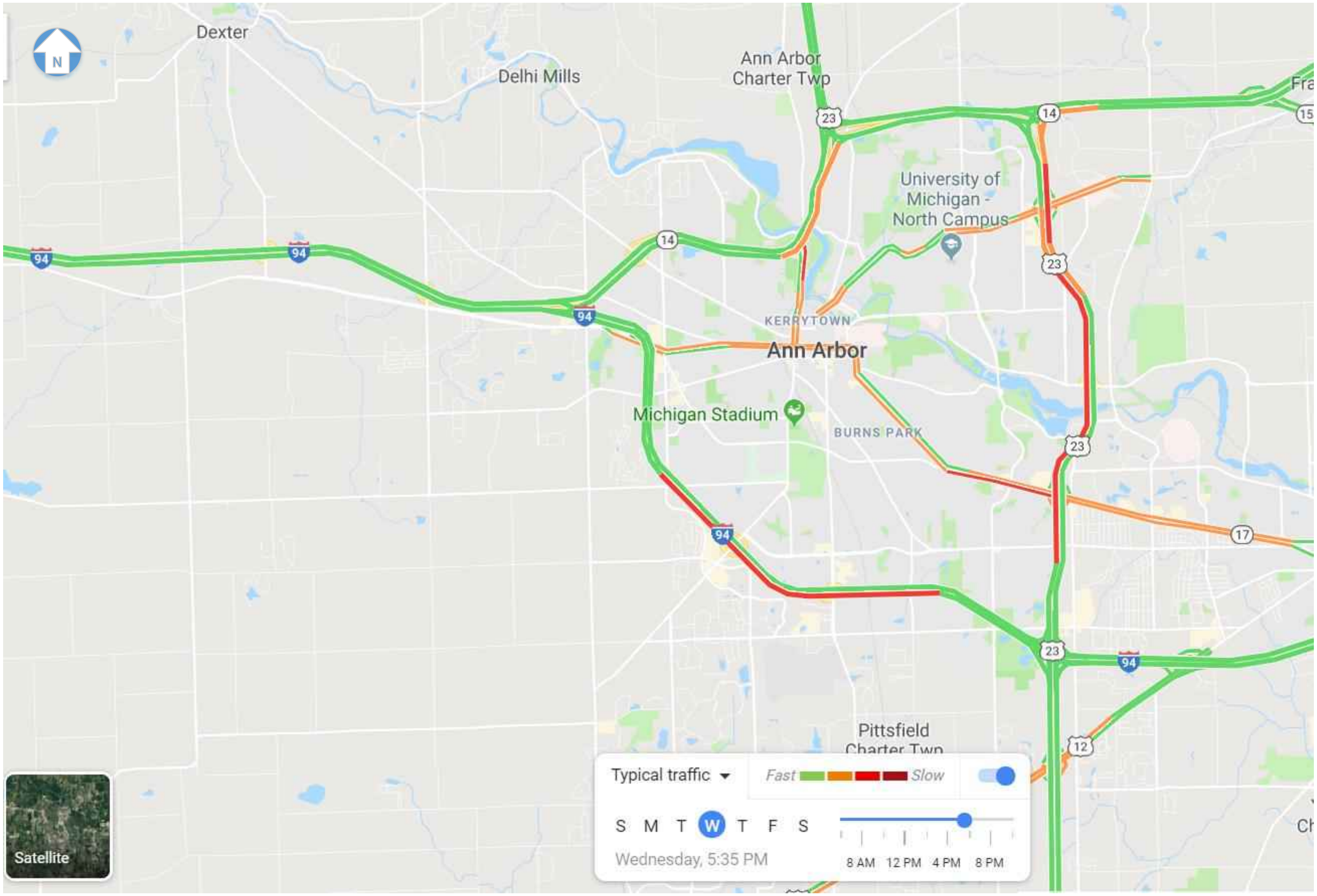



**Figure 12: Typical Congestion PM Commuter Rush (Google)**

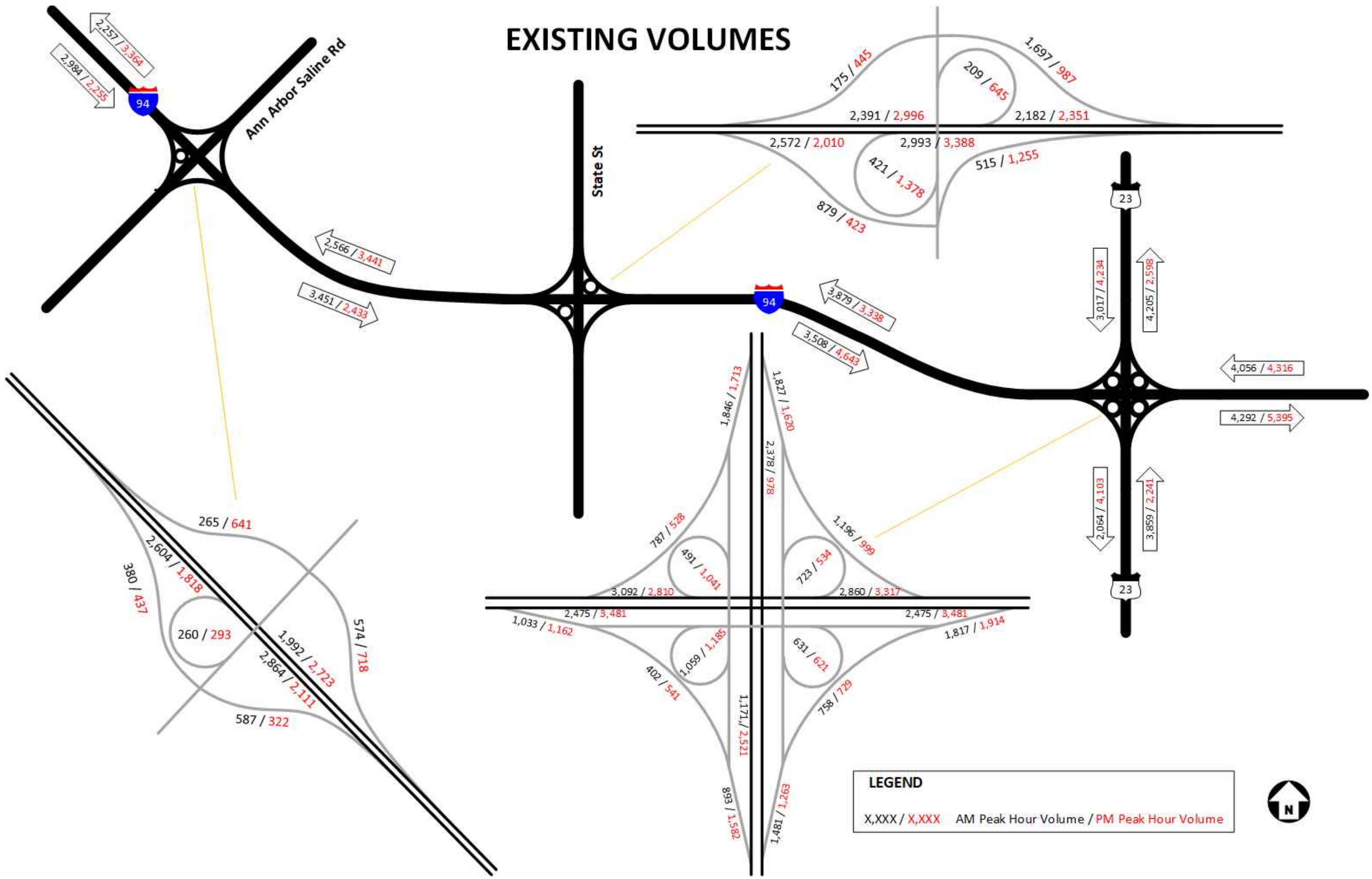



**Figure 13: Existing 2018 Peak Hour Traffic Volumes**

The operations analysis for the Baseline Conditions (2018) was conducted using VISSIM 10. VISSIM is a microsimulation analysis software, in which traffic movements are explicitly modeled based on geometric parameters, traffic volumes, vehicle types, intersection control, and driver behavior. VISSIM assesses the roadway network in a dynamic fashion, instead of analyzing each intersection or each roadway segment in isolation.

Both an AM and PM peak period model were created for a typical weekday. Temporal limits were also established for the microsimulation modeling effort. The AM peak period for this analysis was from 6:30 AM to 10:00 AM; a 3.5-hour period to capture the buildup of congestion, the peak congested period, and the recovery period that occurs along westbound I-94. The PM peak period was from 2:45 PM to 6:45 PM; a 4-hour period to capture the buildup of congestion, the peak congested period, and the recovery period that occurs along eastbound I-94.

The modeling methodology as well as the calibration and validation of these two peak period models were approved by both MDOT and FHWA, with a detailed description of both the methodology and calibration/validation process provided in Appendix A.

## TRAVEL DEMAND FORECASTING

2045 was established as the desired future year for the improvement concepts analysis by MDOT. In other words, improvement concepts recommended as part of this report should be expected to provide acceptable operations through 2045. The traffic growth factors to establish future 2045 conditions were provided by MDOT's Planning Department in coordination with the Southeast Michigan Council of Governments (SEMCOG) Regional Travel Demand Model. The growth rates were applied to the calibrated and validated 2018 Base Conditions VISSIM models to grow the traffic volumes to anticipated 2045 conditions and create the Future No-Build models (FNB). Table 5 contains the growth factors that were utilized for this analysis along the freeways within the study limits. Figure 14 illustrates the anticipated traffic volumes for the year 2045 within the study area for the AM and PM peak hour (7:00 AM – 8:00 AM; 4:30 PM – 5:30 PM). Note that all traffic volumes within these figures are directional in nature.

**Table 5: Future Condition Growth Factors**

| Facility | Growth (%) | |
|---|---|---|
| | AM | PM |
| I-94 EB | 21.99 | 8.67 |
| I-94 WB | 5.34 | 16.80 |
| US-23 NB | 8.14 | 9.76 |
| US-23 SB | 11.86 | 15.57 |

*Note: Growth reported is total growth from 2018 to 2045*

The FNB models provide an estimate of operational performance in 2045 should no improvements be made to the transportation network other than those already programmed for construction between now and 2045. These models serve as the base for comparison against all improvement concepts. The only improvement within the study area that MDOT recommended to be included as part of the FNB condition was the construction of an auxiliary lane along northbound US-23 between US-12 (Michigan Avenue) and the exit ramp to the NB US-23 collector-distributor roadway.

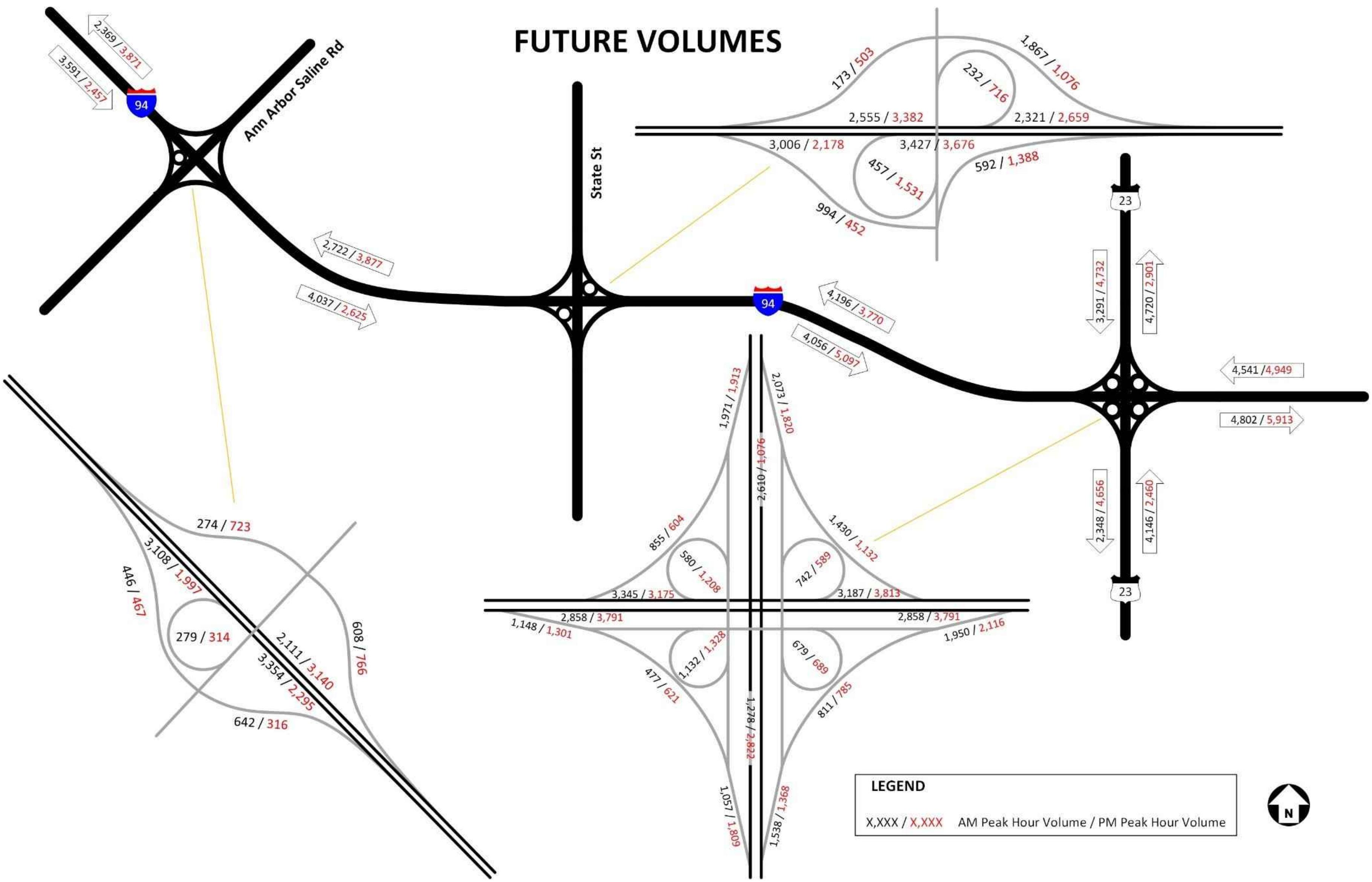



**Figure 14: Estimated 2045 Peak Hour Traffic Volumes**

## FREEWAY MEASURES OF EFFECTIVENESS

The freeway segments within the study area were analyzed to determine the existing operational performance of the interstate network. For the purposes of this analysis, density and level of service (LOS) were reported for each basic freeway segment, ramp merge area, weave area, and ramp diverge area. Density thresholds for the level of service equivalent of each of these segment types are listed in the *Highway Capacity Manual* (6th Edition). A general summary of the LOS grades for freeway operations is presented in Table 6.

**Table 6: Freeway Level of Service Descriptions**

| Level of Service | Description |
|---|---|
| **A** | Free-flow operations and vehicles are almost completely unimpeded in their ability to maneuver within the traffic stream. |
| **B** | Reasonably free-flow operations and the ability to maneuver within the traffic stream is only slightly restricted. |
| **C** | Traffic flow with speeds near free-flow speed. Freedom to maneuver within the traffic stream is noticeably restricted and lane changes require more care and vigilance on the part of the driver. |
| **D** | Level at which speeds begin to decline with increasing flows, with density increasing more quickly. Freedom to maneuver within the traffic stream is seriously limited, and drivers experience reduced comfort levels. |
| **E** | Describes operation at or near capacity. Operations on the freeway at this level are highly volatile because there are virtually no usable gaps within the traffic stream, leaving little room to maneuver within the traffic stream. |
| **F** | Describes unstable flow. Such conditions exist within queues forming behind bottlenecks. Breakdown occurs when the ratio of existing demand to actual capacity exceeds 1.0. |

*Source: Highway Capacity Manual 6th Edition*

It is important to note that the methodology for calculating the LOS based on the Highway Capacity Manual (6th Edition) is formula based. VISSIM, however, produces values from the microsimulation on a lane-by-lane basis for each of the freeway segments, which are then used as inputs to determine the density for each respective segment in a similar manner to the *Highway Capacity Manual* (6th Edition) methodology. The results from these computations for the AM peak hour and PM peak hour are displayed in Tables 7 and 8 and are the average of 10 simulation runs for each time period. More detailed results are provided in Appendix D. In addition to the tabular results, lane schematics were created to report peak hour volume, density, and average travel speed from the VISSIM models down to the individual travel lanes within the study area. Examples of these lane schematics are shown in Figure 15 and Figure 16. Full lane schematic summaries for the for the Existing and Future No-Build conditions are found in Appendix D.

It should be noted that the modeled area was expanded from the project study area (Figure 1) to account for upstream metering of traffic into the primary study area and to fully capture the extents of existing congestion.

## Table 7: Existing (2018) and Future No-Build (2045) Freeway Level of Service Results – I-94 EB Peak Hour

| I-94 Eastbound<br>Segment | Type | AM LOS | | PM LOS | |
|---|---|---|---|---|---|
| | | Existing | FNB | Existing | FNB |
| I-94 EB | basic | C | D | B | E |
| Ann Arbor-Saline Rd Off Ramp | diverge | C | F | B | F |
| I-94 EB | basic | C | E | B | F |
| Ann Arbor-Saline Rd SB On Ramp | merge | C | F | B | F |
| I-94 EB | basic | C | F | B | F |
| Ann Arbor-Saline Rd NB On Ramp | merge | D | F | C | F |
| I-94 EB | basic | D | D | E | F |
| State St Off Ramp | diverge | C | C | F | F |
| I-94 EB | basic | C | D | F | F |
| State St SB On Ramp | merge | C | F | F | F |
| I-94 EB | basic | D | F | F | F |
| State St NB On Ramp | merge | D | F | F | F |
| I-94 EB | basic | D | D | D | D |
| US-23 Off Ramp | diverge | D | D | D | D |
| I-94 EB | basic | C | C | C | C |
| US-23 On Ramp | merge | C | C | C | C |
| I-94 EB | basic | C | C | C | C |
| US-12 (Michigan Ave) Off Ramp | diverge | B | C | C | C |
| I-94 EB | basic | C | C | C | C |
| US-12 (Michigan Ave) SB On Ramp | merge | C | C | C | C |
| I-94 EB | basic | C | C | C | D |
| US-12 (Michigan Ave) NB On Ramp | merge | C | D | D | D |
| I-94 EB | basic | C | D | D | D |
| Huron St Off Ramp | diverge | C | C | D | F |
| I-94 EB | basic | C | C | C | D |
| Huron St SB On Ramp | merge | C | C | C | C |
| I-94 EB | basic | C | D | C | D |
| Huron St NB On Ramp | merge | C | D | C | D |
| I-94 EB | basic | C | D | D | D |
| US-12 (Michigan Ave) Off Ramp | diverge | C | D | D | D |
| I-94 EB | basic | C | C | C | C |

| I-94 Eastbound Collector-Distributor<br>Segment | Type | AM LOS | | PM LOS | |
|---|---|---|---|---|---|
| | | Existing | FNB | Existing | FNB |
| US-23 Distributor | basic | C | D | C | C |
| US-23 SB Off Ramp | diverge | B | C | B | B |
| US-23 Distributor | basic | A | D | A | A |
| US-23 SB On Ramp/US-23 NB Off Ramp | weave | C | F | C | C |
| US-23 Collector | basic | C | C | C | C |
| US-23 NB On Ramp | merge | C | C | C | C |

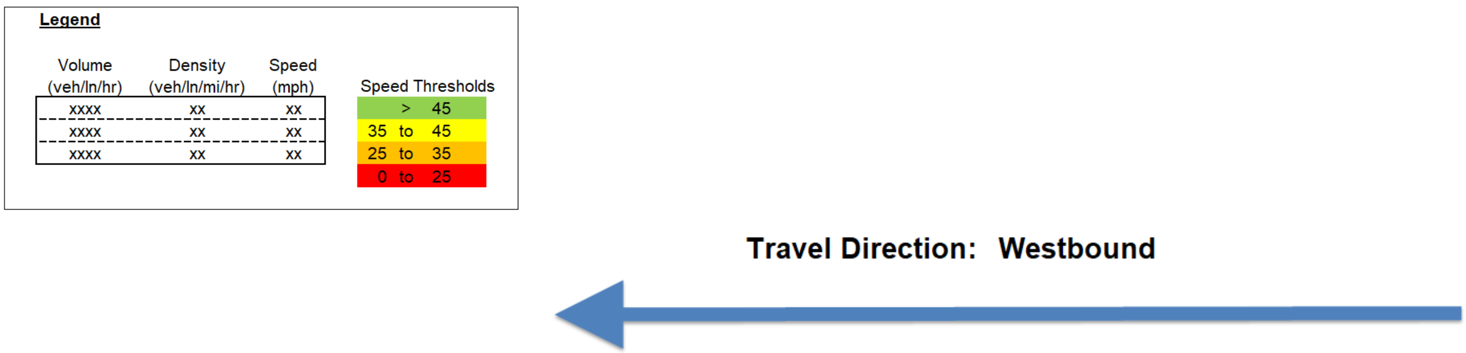
**Table 8: Existing (2018) and Future No-Build (2045) Freeway Level of Service Results – I-94 WB Peak Hour**

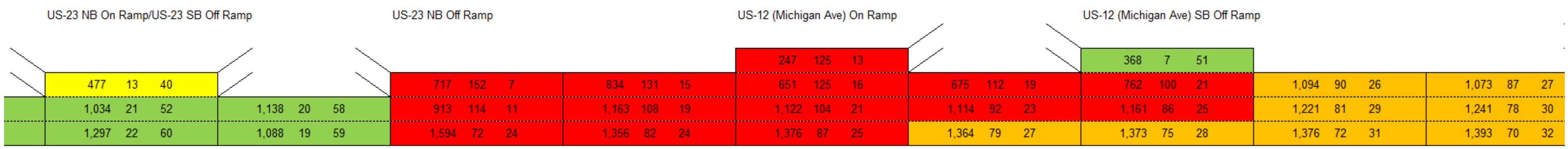
| I-94 Westbound | Type | AM LOS | | PM LOS | |
|---|---|---|---|---|---|
| Segment | | Existing | FNB | Existing | FNB |
| I-94 WB | basic | B | D | B | C |
| US-12 (Michigan Ave) On Ramp | merge | C | F | B | C |
| I-94 WB | basic | D | F | C | D |
| Huron St Off Ramp | diverge | D | F | C | D |
| I-94 WB | basic | E | F | C | C |
| Huron St NB On Ramp | merge | F | F | C | C |
| I-94 WB | basic | F | F | C | C |
| Huron St SB On Ramp | merge | F | F | C | C |
| I-94 WB | basic | F | F | C | D |
| US-12 (Michigan Ave) NB Off Ramp | diverge | F | F | C | D |
| I-94 WB | basic | F | F | C | D |
| US-12 (Michigan Ave) SB Off Ramp | diverge | F | F | B | C |
| I-94 WB | basic | F | F | C | C |
| US-12 (Michigan Ave) On Ramp | merge | F | F | C | C |
| US-23 NB Off Ramp | basic | F | F | C | D |
| I-94 WB | basic | C | B | C | D |
| US-23 NB On Ramp/US-23 SB Off Ramp | weave | B | B | C | D |
| I-94 WB | basic | C | B | C | D |
| US-23 SB On Ramp | merge | C | B | C | D |
| I-94 WB | basic | C | C | C | D |
| State St Off Ramp | diverge | C | B | C | C |
| I-94 WB | basic | B | A | B | C |
| State St NB On Ramp | merge | B | B | C | C |
| I-94 WB | basic | B | B | C | C |
| State St SB On Ramp | merge | B | B | C | D |
| I-94 WB | basic | B | B | C | D |
| Ann Arbor-Saline Rd Off Ramp | diverge | B | B | C | C |
| I-94 WB | basic | B | A | C | C |
| Ann Arbor-Saline Rd On Ramp | merge | B | B | C | C |
| I-94 WB | basic | B | B | C | D |

# Westbound I-94

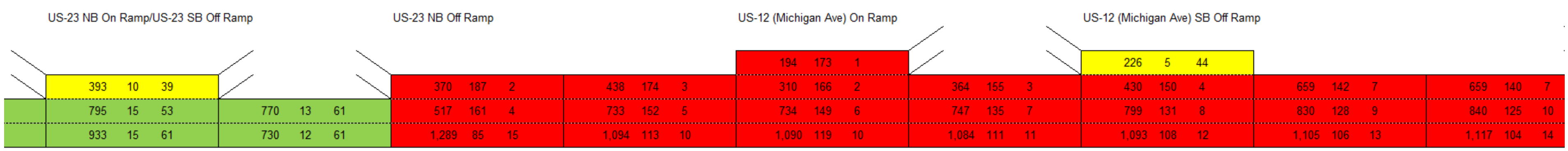
**Time: AM Peak**

## VISSIM OUTPUT: Volume, Density and Speed




Existing (2018)




Future No-Build (2045)

**Figure 15: Existing (2018) and Future No-Build (2045) Lane Schematic MOE Summary (AM Peak Hour) Example**

## Eastbound I-94

**Time: PM Peak**

## VISSIM OUTPUT: Volume, Density and Speed


**Figure 16: Existing (2018) and Future No-Build (2045) Lane Schematic MOE Summary (PM Peak Hour) Example**

## SURFACE STREET MEASURES OF EFFECTIVENESS

The intersections within the study area were also analyzed to determine the existing operational performance of the surface street network. The MOEs used to measure the performance of the intersections in this analysis were intersection delay and LOS.

For intersections, the LOS can be computed for an individual movement, an entire approach, or a whole intersection. The thresholds are also different based on the type of signal control present. The LOS criteria utilized in this analysis are from the *Highway Capacity Manual* (6th Edition) and are displayed in Table 9 and Table 10. Table 9 contains the LOS thresholds for signalized intersections, while Table 10 depicts the LOS thresholds for unsignalized intersections.

The other surface street MOE considered in this analysis is queue length. For the intersections within the study area, two queue-related MOEs were collected: (1) average queue length and (2) maximum queue length.

**The surface street MOEs are summarized in Table 11 through 13. Table 11 displays the LOS results, while**

Table 12 contain the queue length information. Note that the results in both tables are averaged over 10 simulations during the AM peak period and PM peak period, as previously discussed.

**Table 9: LOS Thresholds for Signalized Intersections**

| LOS | Description | Average Control Delay per Vehicle (s) |
|---|---|---|
| A | Operations with very low control delay occurring with favorable progression and/or short cycle lengths. | ≤ 10.0 |
| B | Operations with low control delay occurring with good progression and/or short cycle lengths. | > 10.0 and ≤ 20.0 |
| C | Operations with average control delay occurring with fair progression and/or long cycle lengths. Individual cycle failures begin to appear. | > 20.0 and ≤ 35.0 |
| D | Operations with longer control delay occurring with unfavorable progression, longer cycle lengths, and/or high volume-to-capacity ratios. Individual cycle failures are noticeable. | > 35.0 and ≤ 55.0 |
| E | Operations with high control delay occurring with poor progression, longer cycle lengths, and/or high volume-to-capacity ratios. Individual cycle failures are frequent. This is considered the limit of acceptable delay. | > 55.0 and ≤ 80.0 |
| F | Operations with unacceptable control delay occurring with poor progression, longer cycle lengths, and/or oversaturation. | > 80.0 |

**Table 10: LOS Thresholds for Unsignalized Intersections**

| LOS | Description | Average Control Delay per Vehicle (s) |
|---|---|---|
| A | Operations with very low control delay. | ≤ 10.0 |
| B | Operations with low control delay. | > 10.0 and ≤ 15.0 |
| C | Operations with average control delay. | > 15.0 and ≤ 25.0 |
| D | Operations with longer control delay. | > 25.0 and ≤ 35.0 |
| E | Operations with high control delay. This is considered the limit of acceptable delay. | > 35.0 and ≤ 50.0 |
| F | Operations with unacceptable control delay. | > 50.0 |

**Table 11: Surface Street LOS Results – Existing 2018 and Future No-Build 2045**

| Intersection | LOS (delay/veh) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | AM | | | | PM | | | |
| | Existing | | FNB | | Existing | | FNB | |
| AA Saline and EB 94 | 53.4 | D | 79.1 | E | 28.8 | C | 48.0 | D |
| AA Saline and WB 94 | 23.4 | C | 26.0 | C | 40.4 | D | 62.4 | E |
| State and EB 94 | 15.5 | B | 41.5 | D | 37.9 | D | 155.7 | F |
| State and WB 94 | 22.4 | C | 25.1 | C | 28.2 | C | 30.9 | C |

*Note: Delay is measured in seconds/vehicle*

**Table 12: Surface Street Queue Results – Existing 2018 and Future No-Build 2045 (AM Peak Hour)**

| Intersection | Existing: AM Peak Hour | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Queue Length (ft) | | | | | | | |
| | NB | | SB | | EB | | WB | |
| | Avg | Max | Avg | Max | Avg | Max | Avg | Max |
| **AA Saline and EB 94** | 11 | 216 | 3 | 105 | 20 | 136 | - | - |
| **AA Saline and WB 94** | 31 | 309 | 14 | 228 | - | - | 33 | 235 |
| **State and EB 94** | - | - | 34 | 319 | 88 | 958 | - | - |
| **State and WB 94** | 64 | 506 | - | - | - | - | 148 | 707 |
| **Intersection** | **FNB: AM Peak Hour** | | | | | | | |
| **AA Saline and EB 94** | 154 | 838 | 3 | 105 | 23 | 158 | - | - |
| **AA Saline and WB 94** | 38 | 386 | 16 | 239 | - | - | 34 | 251 |
| **State and EB 94** | - | - | 40 | 344 | 129 | 1194 | - | - |
| **State and WB 94** | 76 | 609 | - | - | - | - | 115 | 679 |

**Table 13: Surface Street Queue Results – Existing 2018 and Future No-Build 2045 (PM Peak Hour)**

| Intersection | Existing: PM Peak Hour | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Queue Length (ft) | | | | | | | |
| | NB | | SB | | EB | | WB | |
| | Avg | Max | Avg | Max | Avg | Max | Avg | Max |
| **AA Saline and EB 94** | 7 | 211 | 24 | 389 | 22 | 184 | - | - |
| **AA Saline and WB 94** | 20 | 205 | 231 | 1101 | - | - | 44 | 205 |
| **State and EB 94** | - | - | 321 | 1324 | 50 | 271 | - | - |
| **State and WB 94** | 52 | 341 | - | - | - | - | 119 | 522 |
| **Intersection** | **FNB: PM Peak Hour** | | | | | | | |
| **AA Saline and EB 94** | 8 | 224 | 27 | 408 | 22 | 202 | - | - |
| **AA Saline and WB 94** | 23 | 248 | 534 | 1390 | - | - | 46 | 220 |
| **State and EB 94** | - | - | 2036 | 2677 | 49 | 305 | - | - |
| **State and WB 94** | 57 | 372 | - | - | - | - | 139 | 589 |

# 3 PURPOSE & NEED

One of the first tasks of the Local Stakeholder Group was to review the Baseline Conditions for the I-94 corridor and develop a Purpose & Need (P&N) statement. The P&N formalizes what the purpose of the project will be (the objectives) and identifies the needs for the project. This step helps focus the range of improvement concepts that are subsequently developed, i.e. improvement concepts should specifically address elements of the P&N or be dismissed. In shaping the P&N, consideration was also given to previous studies and planning documents that include the immediate study area, such as the *South State Street Corridor Transportation Study* (2017), *City of Ann Arbor's Transportation Master Plan*, and *Pittsfield Township's Master Plan*. Comments on the P&N were also received from the public before finalizing the P&N statement after the first public meeting on November 7, 2019 and subsequent online survey that closed December 13, 2019.

The following is the finalized P&N as a result of this stakeholder and public engagement process. Metrics for the objectives were developed to compare the range of improvement concepts discussed in the next chapter. Per the input from the stakeholder group, improvement concepts should not preclude future transit or rideshare plans within the region.

## 3.1 PURPOSE OF THE PROPOSED PROJECT

The purpose of the proposed improvement concepts to the I-94 corridor is to enhance overall mobility, reliability, and safety along I-94 within the study area. The improvements will help improve the efficiency of an important international trade corridor that is vital to Michigan and the U.S. economy. Specific objectives include the following:

- Reduce recurring peak period congestion along the corridor and improve travel time reliability;
- Enhance safety for all roadway users on this portion of the interstate system and interchanges;
- Provide reasonable capacity to address existing and 20-year forecasted 2045 traffic demand along the corridor; and,
- Eliminate and minimize existing substandard design elements, where feasible, that contribute to operational and safety issues.

## 3.2 NEED FOR THE PROPOSED PROJECT

I-94 is a vital component of the transportation network in Michigan and the United States. It is a major east-west route extending nearly 1,500 miles from Michigan's eastern border with Canada at the Blue Water Bridge international crossing in Port Huron to the western limit in Billings, Montana. It is a key commercial route for both international and national trade, moving people and goods across the state and country daily. As one of the busiest trade corridors in the United States, it is vital to the economic competitiveness of Michigan and the nation. It is also a significant regional commuter route within the project limits, serving the Ann Arbor and greater Detroit metropolitan region. The segment between State Street and US-23 is in the top 10 of the highest volume two-lane freeway segments in Michigan with an annual average daily traffic (AADT) of approximately 94,000 (2019). The freeway carries high directional volumes during peak periods, resulting in frequent periods of congestion during the AM and PM commuter rush hours as the roadway capacity has not kept pace with the growing traffic demand. Outside of these peak times, operations are generally free-flow unless there is an incident or, seasonally, for University of Michigan football games. These periods of congestion not only impact I-94, but also regularly impact operations along US-23 at the system interchange and are a major contributor to user-delay within the region. In addition, a relatively high frequency of crashes due to congestion regularly impacts corridor flow leading to volatile and unreliable travel times.

This portion of I-94 was built in the 1950s. Since original construction, a median barrier was constructed in 1975 and some bridge rehabilitation occurred throughout the 1970s to 1980s. The corridor and has not received any significant geometric improvements since the 1950s.

In summary, specific factors directly contributing to the need for this project are as follows:

<u>*Operations*</u>

- Recurring westbound I-94 congestion during the AM peak period regularly queues from the State Street interchange (Exit 177) to the US-12 Entrance ramp near Willow Run Airport leading to excessive user delays.
- Recurring eastbound I-94 congestion during the PM peak period regularly queues from the State Street interchange to the Ann Arbor-Saline Road interchange.
- I-94 congestion regularly spills back and impacts the surface street network at State Street leading to excessive user delays.
- Existing and 20-yr forecasted travel demand exceeds existing capacity of the corridor.
- Operational volatility due to congestion and regular crashes leads to poor travel time reliability.

<u>*Safety*</u>

- This portion of I-94 has the highest frequency of crashes and second highest crash rate along I-94 between M-60 (Jackson, Michigan) and I-275.
- This portion of I-94 has the highest frequency and rate of *severe* crashes along I-94 between M-60 (Jackson, Michigan) and I-275.
- There is a high frequency of congestion related crashes within the study corridor.
- There is a concentration of crashes along westbound I-94 in the weave area between the two loop ramps at the US-23 system interchange.
- The eastbound I-94 exit ramp to northbound State Street movement has a crash trend on the interchange bridge deck where this movement merges with the free-flowing northbound State Street traffic.

<u>*Geometrics*</u>

- Horizontal stopping sight distance along I-94 is substandard for a 70 mph speed limit through the US-23 system interchange.
- Vertical clearance is substandard for the following bridges which are also approaching their design life:
  - Stone School Road over I-94 (*constructed in 1954*)
  - Pedestrian/Bicycle bridge at Stone School Road over I-94 (*constructed in 1975*)
  - Pedestrian bridge at Plainview Court over I-94 (*constructed in 1975*)
- Entrance ramp tapers are substandard for the following:
  - All entrance ramps at US-23 system interchange
  - All entrance ramps at State Street interchange
  - All entrance ramps at Ann Arbor-Saline Road interchange
- Exit ramp tapers are substandard for the following:
  - Westbound I-94 to Northbound State Street
  - Westbound I-94 to Northbound Ann Arbor-Saline Road

- Shoulder widths are substandard for the following:
  - Left shoulder of all ramps with US-23 system interchange
  - Left shoulder of all ramps of State Street interchange, except the southbound State Street to eastbound I-94 loop ramp
  - Left shoulder of all ramps of Ann Arbor-Saline Road interchange, except the westbound I-94 to northbound Ann Arbor-Saline Road ramp
- The vertical curve for both eastbound and westbound I-94 over the railroad just east of State Street, only meets current standards for 60 mph.

# 4 CONCEPTS ANALYSIS

## 4.1 CONCEPT DEVELOPMENT OVERVIEW

Preliminary concepts were developed by the Local Stakeholder Group using the Purpose & Need statement as a guide to address the safety and operational issues identified during the Baseline Conditions analysis. Three (3) core issues were identified for improvement concepts to address:

1. ***I-94 mainline mobility*** – Reduce congestion and improve safety and reliability of the I-94 corridor.
2. ***Westbound I-94 to northbound US-23 bottleneck*** – Reduce the congestion associated with this movement, particularly in the AM commuter rush.
3. ***Westbound I-94 at US-23 system interchange safety*** – Improve safety at this high crash location.

Figure 17 is an overview of the concept development and refinement process used for this study. Details regarding each of these steps follows:

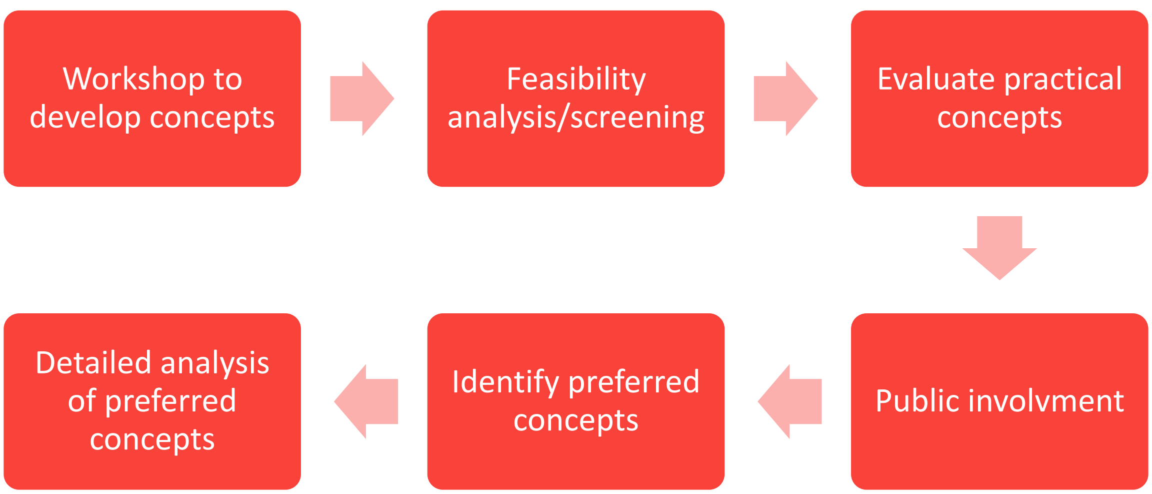



**Figure 17: Concept Development Process Work Flow**

- **Workshop to develop concepts:** A one-day concept development workshop was conducted with the Local Stakeholder Group (August 8, 2019) where a variety of preliminary improvement concepts were identified through a brainstorming session among committee representatives. These concepts included the initial concepts explored by MDOT in their 2016 study of the corridor. In total, 20 different improvement concepts were identified during the workshop. A listing of the various concepts is found in Appendix C.
- **Feasibility analysis/screening:** The initial set of 20 improvement concepts were vetted in a high-level feasibility screening to determine which concepts could be eliminated due to being fatally flawed,

impractical, or not meeting the Purpose & Need. The concepts identified as feasible during this screening process were advanced for additional analysis as practical concepts.

- **Evaluate practical concepts:** Preliminary analysis was conducted on the practical concepts to estimate each concept's impact on operations, safety, right of way (ROW), design, environmental considerations, and cost. The findings of these preliminary analyses were presented to the Local Stakeholder Group which led to further refinement and identification of practical concepts that could be advanced for the public to provide feedback on.
- **Public involvement:** The study's Purpose & Need and practical concepts were presented to the public to provide comment on. Comments were received through a public meeting held on November 7, 2019, as well as through a virtual public involvement (VPI) survey via the internet. Additional detail on the public involvement is summarized in Section 4.5.
- **Identify preferred concepts:** Based on the previous analyses and feedback from the public, preferred improvement concepts are selected that meet the Purpose & Need and are advanced for further analysis and refinement.
- **Detailed analysis of preferred concepts:** Detailed evaluations of operations, safety, and design and environmental considerations are conducted for the preferred concepts. This included conceptual level plan view layouts in CADD of the preferred concepts and more refined construction cost estimates.

The remainder of this chapter describes the specific improvement concepts developed to address the three core issues, the public involvement conducted, and a summary of the recommended improvement concepts.

## 4.2 I-94 MAINLINE MOBILITY IMPROVEMENT CONCEPTS

The I-94 mainline improvement concepts generally took one of two forms; the addition of a continuous third travel lane in both directions of I-94 within the study area, or the addition of discontinuous travel lanes between interchanges (auxiliary lanes). The continuous and discontinuous lanes could be constructed in a variety of ways including conventional widening, restriping only, or the use of part-time shoulder running operation (flex lanes). Based on Local Stakeholder Group input and feedback from the public, six variations on the continuous and discontinuous lane concepts were explored in detail.

The six concepts analyzed along mainline I-94 are described in Table 14 and the conceptual project limits of each shown in Figure 18:

**Table 14: I-94 Mainline Concepts**

| Concept | Description |
|---|---|
| **1A**<br>**Continuous 3rd Lane (Standard)** | • Continuous 3rd travel lane on the inside of EB and WB I-94 added as a full reconstruct of the corridor to current design standards<br>• EB I-94 limits: northbound Ann Arbor-Saline Road entrance ramp to the US-12 (Michigan Avenue) exit ramp<br>• WB I-94 limits: exit ramp to NB US-23 to exit ramp to Ann Arbor-Saline Road |
| **1B**<br>**Continuous 3rd Lane (PBPD)** | • Continuous 3rd travel lane on the inside of EB and WB I-94 added as a full reconstruct of the corridor using a combination of current design standards and performance based practical design (PBPD) methods (narrowing of shoulders in select areas) to maximize operational and safety improvements while eliminating non-essential design elements that significantly impact cost and do not provide substantial value to the project in addressing the purpose and need<br>• EB I-94 limits: northbound Ann Arbor-Saline Road entrance ramp to the US-12 (Michigan Avenue) exit ramp<br>• WB I-94 limits: entrance ramp from SB US-23 to exit ramp to Ann Arbor-Saline Road |
| **1C**<br>**Continuous 3rd Lane (Flex)** | • Continuous 3rd travel lane on the inside of EB and WB I-94 added through resurfacing and shoulder widening/reconstruction along the corridor such that the inside shoulder is a "Flex Lane" used as the 3rd travel lane during peak periods and a typical shoulder during off-peak times<br>• EB I-94 limits: northbound Ann Arbor-Saline Road entrance ramp to the US-12 (Michigan Avenue) exit ramp<br>• WB I-94 limits: entrance ramp from SB US-23 to exit ramp to Ann Arbor-Saline Road |

**Table 14: I-94 Mainline Concepts (continued)**

| Concept | Description |
|---|---|
| **1D**<br>**Continuous 3rd Lane (Restripe)** | • Continuous 3rd travel lane on the inside of EB and WB I-94 added as a mill and overlay with restriping only and using PBPD methods (narrowing of shoulders and travel lanes) to maximize operational and safety improvements while eliminating non-essential design elements that significantly impact cost but do not provide substantial value to the project in addressing the purpose and need<br>• EB I-94 limits: northbound Ann Arbor-Saline Road entrance ramp to the US-12 (Michigan Avenue) exit ramp<br>• WB I-94 limits: entrance ramp from SB US-23 to exit ramp to Ann Arbor-Saline Road |
| **2A**<br>**Discontinuous 3rd Lane (Standard Aux)** | • Discontinuous 3rd lanes on the outside of existing EB and WB I-94 are to be used as auxiliary lanes through HMA widening<br>• EB I-94 limits: 1) Auxiliary lane between northbound Ann Arbor-Saline Road entrance ramp to State Street exit ramp; 2) Auxiliary lane between NB State Street entrance ramp and US-23 CD exit ramp<br>• WB I-94 limits: 1) Auxiliary lane between the entrance ramp from SB US-23 to State Street exit ramp |
| **2B**<br>**Discontinuous 3rd Lane (Aux Flex)** | • Discontinuous 3rd lanes provided on the outside of EB and WB I-94 through a mill and overlay and HMA shoulder widening to turn the outside shoulder into a "Flex Lane" used as the 3rd lane (auxiliary lane) during peak periods and a typical shoulder during off-peak times<br>• EB I-94 limits: 1) Auxiliary Flex lane between northbound Ann Arbor-Saline Road entrance ramp to State Street exit ramp; 2) Auxiliary Flex lane between NB State Street entrance ramp and US-23 CD exit ramp<br>• WB I-94 limits: 1) Auxiliary Flex lane between the entrance ramp from SB US-23 to State Street exit ramp |

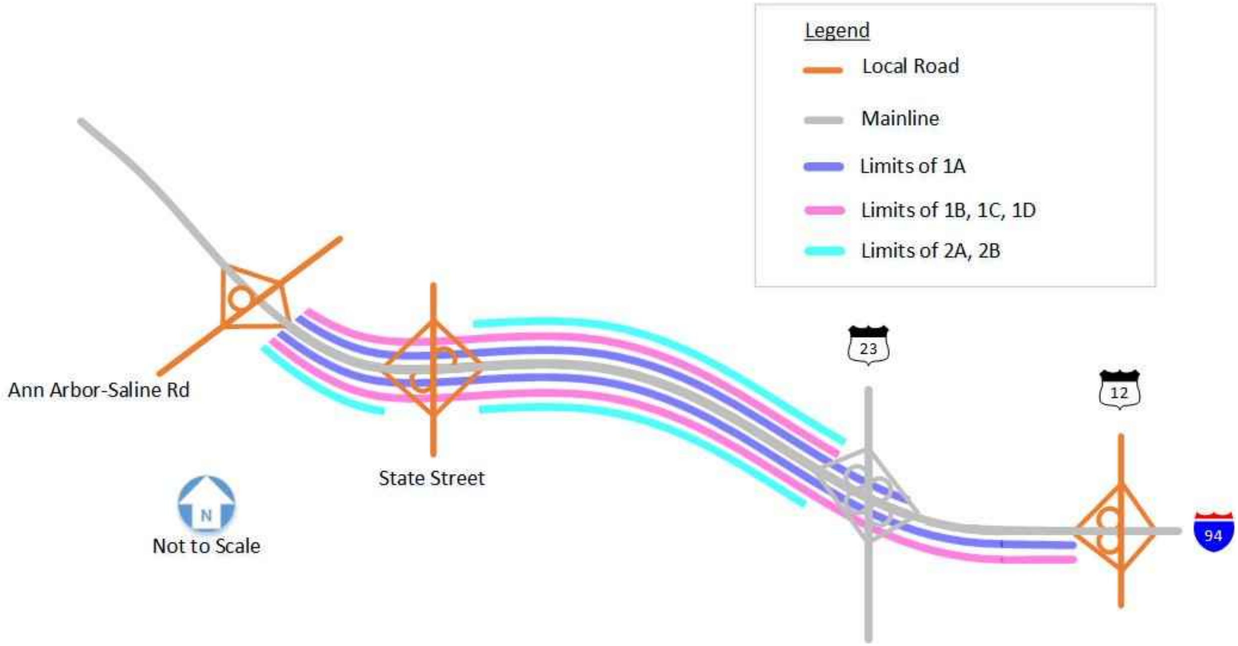



**Figure 18: Project Limits - I-94 Mainline Concepts**

## OPERATIONS

An operational review was performed for each of the six I-94 mainline concepts using microsimulation (VISSIM). 2045 AM and PM peak period models for each of the six I-94 mainline concepts were created by modifying the Future No-Build models to reflect the proposed geometric changes and operational strategies.

To determine the operational benefits associated with each concept, the following steps were followed:

- Corridor delay along I-94 was calculated for both westbound and eastbound for each time period (results based on an average of 10 simulation runs).
- The corridor delay was multiplied by the number of vehicles experiencing the delay to arrive at a total vehicle-hours of delay value for both passenger vehicles and commercial trucks in each time period.
- The AM and PM peak period values were summed together to arrive at an approximated daily vehicle-hours of delay for both passenger vehicles and commercial trucks.
- The daily vehicle-hours of delay for each concept was compared to the daily vehicle-hours of delay for the No-Build with the difference being the operational benefit of that concept.
- The daily operational benefit (veh-hours) for a concept was monetized using assumptions from MDOT's *C&R Benefit Cost Spreadsheet_v2.1.xlsx* to create an annual operational benefit estimate.

It should also be noted that preliminary analysis indicated the flex lane concepts (1C and 2B) should operate during the following time periods and these were used for estimating the operational benefits:

- Eastbound flex lane operating periods: AM and PM peak periods
- Westbound flex lane operating periods: AM peak period only

Table 15 summarizes the estimated relative operational benefits associated with each concept for the year 2045.

**Table 15: Estimated Operational Benefits by Concept (I-94 Mainline)**

| Time Period | Concept 1A | Concepts 1B & 1D | Concept 1C | Concept 2A & 2B |
|---|---|---|---|---|
| **Daily** | $87.2 K | $86.6 K | $85.2 K | $84.0 K |
| **Annual** | $21.8 M | $21.9 M | $21.3 M | $21.0 M |

Concepts 1B and 1D show slightly more operational benefit than 1A and 1C due to the SB US-23 ramp to WB I-94 being a lane add with these concepts and no merge required for this heavy on-ramp volume as would be required in 1A and 1C. Concepts 2A and 2B (the discontinuous 3rd lane concepts) are anticipated to achieve 96% of the operational benefits when compared to the top performing continuous 3rd lane concepts (1B and 1D).

## SAFETY

A high-level review of the six I-94 mainline concepts was conducted to estimate the potential safety performance of each. Crash data was obtained from the MDOT from 2013 to 2017 within the extents of each concept. The crash data was organized and summarized to account for significant changes in cross section along the corridor by bound and by time of day to estimate impacts of the proposed flex lanes. This primarily impacted Concepts 1B & 1C due to the number of relatively short, discontinuous sections of shoulder reductions. Weighted average shoulder widths were determined for both east and west bounds for these short sections.

Five primary Crash Modification Functions (CMF) were identified to address changes to lane width, inside shoulder width, outside shoulder width, and the impacts of changes to volume proportions. These CMFs are included in the *Highway Safety Manual Supplemental – Chapter 18 Predictive Method for Freeways*. It is important to note that these CMF's represent average results, with each having its own confidence interval. The resultant crash modification factors were calculated using these functions.

- Lane Width – Used to account for changes in through lane width. Applicable for all crashes of all severities.
- Inside Shoulder Width – Used to account for changes in the paved inside shoulder width. Individual CMF's for fatal & injury (F & I) crashes and property damage only (PDO) crashes.
- Outside Shoulder Width – Used to account for changes in the paved outside shoulder width. Tangent and curved variants exist but less than 0.5% of the reported crashes were noted along curved sections in the one-line summaries. As such the tangent CMF was utilized.
- Volume Proportion – Used to estimate the impact of additional lanes based on the proportion of hours in a day with hourly vehicular volumes per lane greater than 1,000. The peak hour volumes for the existing and projected 2045 volumes were used to estimate these CMFs conservatively. This CMF helped to account for projected increases in traffic volume through the study corridor.
- Additional Lane – This CMF was obtained from the Crash Modification Factor Clearing House and was selected to help account for the additional proposed lanes. It was only applicable to fatal and injury crashes based on existing research.

These CMF's were applied, as appropriate, in combination to the various concepts to estimate their relative safety impacts by property damage only, fatal & injury, single motor vehicle, and multiple motor vehicle. The CMFs were applied accordingly, with the results condensed to consider changes to property damage only and fatal and injury crashes. The annual average number of crashes before treatment were estimated and compared to the annual average number of crashes after the proposed treatments. The MDOT Time of Return (TOR) form was used to estimate the Annual Benefit (Present Value with Inflation) to ensure that MDOT supplied values were utilized. Table 16 summarizes the estimated relative safety benefits associated with each concept.

**Table 16: Estimated Safety Performance by Concept (I-94 Mainline)**

| | Description | Annual Avg. Before | | Annual Avg. After | | % Reduction | | Est. Annual Benefit* |
|---|---|---|---|---|---|---|---|---|
| | | PDO | F&I | PDO | F&I | PDO | F&I | |
| 1A | **3rd Lane Continuous** | 213.2 | 56.6 | 212.8 | 40.7 | 0.2% | 28.1% | *$7.1 M* |
| 1B | **3rd Lane Continuous Using PBPD** | 180.4 | 47.8 | 185.8 | 37.9 | -3.0% | 20.7% | *$4.3 M* |
| 1C | **3rd Lane Continuous Flex Lane** | 180.4 | 47.8 | 192.7 | 41.8 | -6.8% | 12.6% | *$2.5 M* |
| 1D | **Restriping** | 178.2 | 46.4 | 202.5 | 41.5 | -13.6% | 10.7% | *$1.8 M* |
| 2A | **Auxiliary Lane Addition Along I-94** | 63.8 | 20.4 | 63.7 | 15.8 | 0.1% | 22.4% | *$2.1 M* |
| 2B | **Auxiliary Lane Addition Along I-94 w/Flex Lane** | 63.8 | 20.4 | 67.4 | 18.9 | -5.6% | 7.1% | *$0.6 M* |

***Present Value w/Inflation***
***PDO = Property Damage Only; F&I = Fatal and Injury***

The Highway Safety Manual (HSM) helps to quantify the effects of various geometric and operational scenarios, along with various safety countermeasures. The research into the HSM was largely based on roadways and crashes between 2000 and 2008 and reflect design standards in place at that time. As such, many design assumptions are inherent in the models and are not expressly considered in the safety performance functions (SPF) or been researched as an explicit crash modification factor (CMF). For example, the location of the cross slope and location of the crown points are assumed to follow normal design standards. Current design standards for freeways would not typically place these design elements within a travel lane, and any deviation would likely have an effect on drivers as this would not be an expected condition.

In other words, Concept 1D is showing a safety benefit based on the HSM analysis, but it is very likely that this is an overestimation of safety improvement due to compounding factors, such as cross slope breaks and crown points within the travel lanes themselves, that would go against current design standards as well as driver expectation and pose a safety concern that are not currently accounted for as part of the HSM research.

## SUMMARY AND RECOMMENDATIONS

Table 17 summarizes the analysis findings for each concept as it relates to design, operations, and safety. It should be noted, that while Concept 1D shows the greatest theoretical benefit-to-cost ratio and quickest return on investment, there are several design and safety concerns associated with this concept (noted in the subsequent section) that would make this concept undesirable. Concepts 2B and 2A rank most favorably, followed by 1C, 1B, and then 1A.

**Table 17: I-94 Mainline Concepts Analysis Summary**

| Concept | Proposed Improvement | *DE/DV Needed | Construction Cost ($) | Annual Operational Benefit ($) | Annual Safety Benefit ($) | *B/C | *ROI (years) |
|---|---|---|---|---|---|---|---|
| **1A Continuous 3rd Lane (Standard)** | Full Reconstruct | 2 | 164 M | 21.8 M | 7.1 M | 0.2 | 5.7 |
| **1B Continuous 3rd Lane (PBPD)** | Full Reconstruct | 6 | 101 M | 21.9 M | 4.3 M | 0.3 | 3.9 |
| **1C Continuous 3rd Lane (Flex)** | Mill & Overlay & Shoulder Reconstruct | 6 | 43.5M | 21.3 M | 2.5 M | 0.5 | 1.8 |
| **1D Continuous 3rd Lane (Restripe)** | Mill & Overlay | 7 | 14 M | 21.9 M | 1.8 M | 1.7 | 0.6 |
| **2A Discontinuous 3rd Lane (Standard Aux)** | Shoulder Reconstruct | 1 | 33.8 M | 21.0 M | 2.1 M | 0.7 | 1.5 |
| **2B Discontinuous 3rd Lane (Aux Flex)** | Mill & Overlay & Shoulder Reconstruct | 4 | 21.6 M | 21.0 M | 0.6 M | 1.0 | 1.0 |

**DE/DV = Design Exception and/or Design Variance*
**B/C = Benefit-Cost ratio (planning level based on 2019 dollars for construction cost and 2045 estimated benefits)*
**ROI = Return on Investment (planning level based on 2019 dollars for construction cost and 2045 estimated benefits)*

It should be noted, MDOT indicated a new driver would need to be added to the existing courtesy patrol contract for either of the two flex lane concepts (1C or 2B) in order to visually sweep and remove any debris from the flex lane. An additional driver would add approximately $100,000 per year to the current contract; however, only two out of the eight hours of a day would be devoted to the I-94 flex lane and the driver would be used in other areas for the remaining six hours of a day. It was reasoned by MDOT, only 25 percent of that $100,000 per year should be applied to this project's cost, or $25,000 per year. This is a relatively minor cost, and even when multiplied by 20 years would equate to approximately $500,000, which when subtracted from the operational benefits is still not significant enough to change the B/C or ROI results as currently reported.

***Recommendations***

**Concept 1D is NOT recommended to be advanced for further consideration** for the following reasons:

- Shoulders on both the inside and outside are not wide enough to be used for emergency stopping within the project limits
- Concept 1D is showing a safety benefit based on the HSM analysis in Table 2, but it is very likely that compounding factors such as cross slope breaks and crown points within the travel lanes themselves, that go against current design standards as well as driver expectation, would pose a safety concern that are not currently accounted for as part of the HSM research
- Limited ability to correct existing pavement breaks and superelevated sections; pavement grade breaks will fall within travel lanes, which would not be expected by drivers
- HMA overlay would result in a higher vertical elevation, lowering current underclearances
- Multiple Design Exceptions/Variances necessary (I-94 lane width, inside shoulder width, outside shoulder width, cross-slopes, superelevation rates, vertical clearance, entrance and exit ramp acceleration/deceleration lengths)
- Mill and overlay is a short-term solution

**Concepts 2A and 2B ARE recommended to be advanced for further study** for the following reasons:

- Concepts 2A and 2B both provide similar operational benefits to Concepts 1A, 1B, and 1C for significantly less construction cost (Concepts 2A and 2B are anticipated to achieve 96% of the operational benefits when compared to the top performing continuous 3$^{rd}$ lane concept 1B)
- Concepts 2A and 2B both provide an anticipated safety improvement over existing conditions
- Concepts 2A and 2B have fewer design exceptions/variances when compared to Concepts 1B and 1C while still meeting the Purpose and Need for the corridor
- Concepts 2A and 2B could facilitate "Bus on Shoulder" (BOS) operations during the "off-peak" time periods

Concepts 2A and 2B also benefit from being able to be broken into smaller stand-alone projects that can help minimize disruptions to the roadway users from a constructability perspective and allows for phased improvements. The relative benefits of each individual project are shown in Table 18.

**Table 18: Concept 2A and 2B Individual Projects Summary**

| Project | Project Description | Recommended Order of Implementation | Construction Cost ($) | Annual Operational Benefit ($) | Annual Safety Benefit ($) | B/C | ROI (years) |
|---|---|---|---|---|---|---|---|
| ***2A-1** | Eastbound Auxiliary (State to US-23) | 1 | 17.3 M | 14.5 M | 0.8 M | 0.9 | 1.1 |
| **2A-2** | Westbound Auxiliary (US-23 to State) | 2 | 14.5 M | 4.5 M | 1.1 M | 0.4 | 2.6 |
| **2A-3** | Eastbound Auxiliary (Ann Arbor-Saline to State) | 3 | 2.0 M | 2.0 M | 0.1 M | 1.1 | 1.0 |
| ****2B-1** | Eastbound Flex Auxiliary (State to US-23) | 1 | 10.4 M | 14.5 M | 0.2 M | 1.4 | 0.7 |
| **2B-2** | Westbound Flex Auxiliary (US-23 to State) | 2 | 9.0 M | 4.5 M | 0.3 M | 0.5 | 1.9 |
| **2B-3** | Eastbound Flex Auxiliary (Ann Arbor-Saline to State) | 3 | 2.2 M | 2.0 M | 0.1 M | 1.0 | 1.0 |

**Bridge reconstruction cost for Stone School, the Railroad Bridge, and the Rayer and Grance Drain assumed in this project but would be part of whichever project went first (2A-1 or 2A-2) and is approximately $10.6 M of the calculated cost.*

***Bridge reconstruction cost for Stone School assumed in this project but would be part of whichever project went first (2B-1 or 2B-2) and is approximately $3.7 M of the calculated cost.*

Concept 2B achieves much of the same benefits as Concept 2A and with a lesser overall construction cost making it the more likely concept to advance as an actual project. A more detailed description of Concept 2B's design considerations follows, and similar detailed analyses for the other concepts can be found in Appendix A, including conceptual design layouts and the preliminary cost estimates.

## RECOMMENDED IMPROVEMENT CONCEPT 2B

Concept 2B is very similar to 2A, except that the outside shoulder would be used as a "flex" auxiliary lane during peak hours and would remain a normal shoulder for emergency stopping only during the off-peak hours. The use of a flex lane would alleviate the need to widen I-94 to establish an additional 8-foot paved shoulder.

The construction limits for the auxiliary flex lanes are proposed as follows:

- ***EB I-94***
  1. An auxiliary flex lane between the NB Ann Arbor-Saline Rd to EB I-94 entrance ramp and the EB I-94 exit ramp to State Street
  2. An auxiliary flex lane between the NB State Street to EB I-94 entrance ramp and the EB I-94 exit ramp to the US-23 collector-distributor
- ***WB I-94***
  1. An auxiliary flex lane between the SB US-23 entrance ramp to WB I-94 and the exit ramp to State Street

***Typical Section***

This option shown below would reduce the existing inside shoulder from 11 feet 10 inches to 10 feet, the two main through lanes are 12 feet, and the part-time flex lane along the outside is 11 feet with 2 feet additional paved shoulder beyond the flex lane (see Figure 19). A full mill and overlay from the face of the median barrier to the outside edge of the two main through lanes is assumed to allow for minor corrections of the normal crown and shoulder slopes. The outside shoulder would be reconstructed to support vehicular travel. Flex lane signage is assumed to be static for the purpose of this analysis but could be dynamic for additional cost allowing for the use of the flex lane outside of normal hours during incidents and unplanned events.

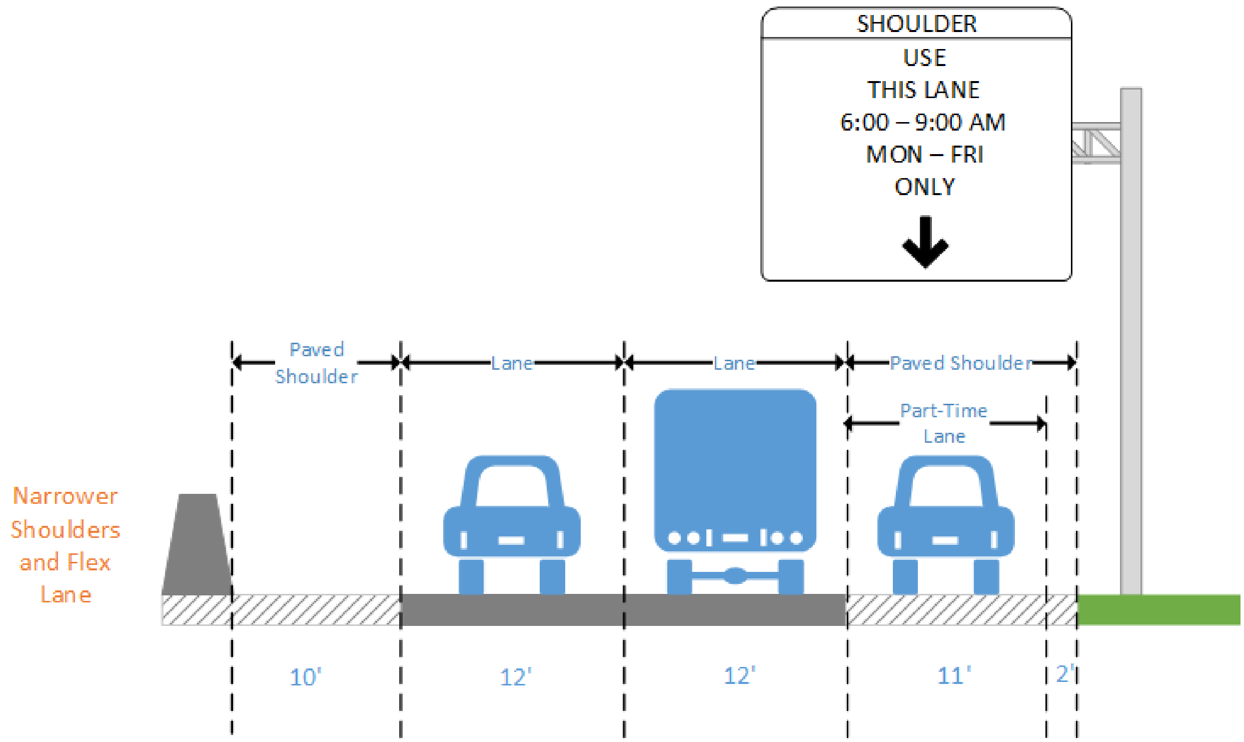



**Figure 19: Concept 2B Typical Section (Schematic)**

***Design Considerations***

This concept would produce the following structural impacts:

1. S06 of 81062 Stone School Rd over I-94 - Bridge will need to be replaced to accommodate third lane.
2. P01 of 81062 Stone School Rd Pedestrian Bridge over I-94 – Would not meet underclearance requirements, so it is assumed this structure is removed and pedestrian crossing to be added to Stone School Road over I-94 bridge replacement.

**Design Exceptions:**

1. Proposed Inside Shoulder Width:
    - EB and WB shoulder will be reduced to 7 feet at R01 of 81602 to avoid structural impacts
2. Proposed Outside Shoulder Width:
    - Outside shoulder width will be reduced to 2 feet in all locations when flex lanes are being utilized
3. Horizontal stopping sight distance: I-94/US-23 Interchange
4. Underclearance:
    - Plainview Court Pedestrian bridge
    - Potential for reduced underclearance due to mill and overlay for all other bridges over I-94

**Design Variances:**

1. Acceleration/deceleration length
    - The deceleration length standard per GEO-140-B is not able to be met for a dual-lane exit ramp for WB I-94 at State Street. A design variance would be needed here to avoid reconstructing the railroad structure.

**ROW Required:**

(None anticipated)

**Environmental:**

1. Clearing: Tree clearing will be required along east and westbound I-94 throughout the corridor limits to regrade side slopes, establish ditch, and maintain the clear zone for the widened roadway. The dense tree line will be narrowed by approximately 5-feet along I-94 in both directions, and wider in locations dependent on drainage ditch elevations and steep side slopes.
2. Noise Abatement: A noise analysis will be required during final design phase to determine locations and heights of noise abatement walls that may be warranted.

**Other Roadway Improvements:**

1. WB I-94 Dual-Lane Exit Ramp at State Street: It was determined during the operational analyses that a dual-lane exit ramp from WB I-94 to State Street would be necessary to accommodate forecasted traffic and mitigate the risk of traffic on this ramp backing up onto mainline I-94. A dual-lane exit should be a planned improvement regardless of the I-94 mainline improvement concept. Figure 20 illustrates how this would work in the context of Concept 2B and a flex-auxiliary lane.
2. EB I-94 Right-Turn Pocket at State Street: It was determined during the operational analyses that an additional right-turn pocket should be constructed for the EB I-94 exit ramp approach at State Street. This is needed to accommodate forecasted traffic and mitigate the risk of traffic on this ramp backing up onto

mainline I-94. The additional turn-pocket should be a planned improvement regardless of the I-94 mainline improvement concept.

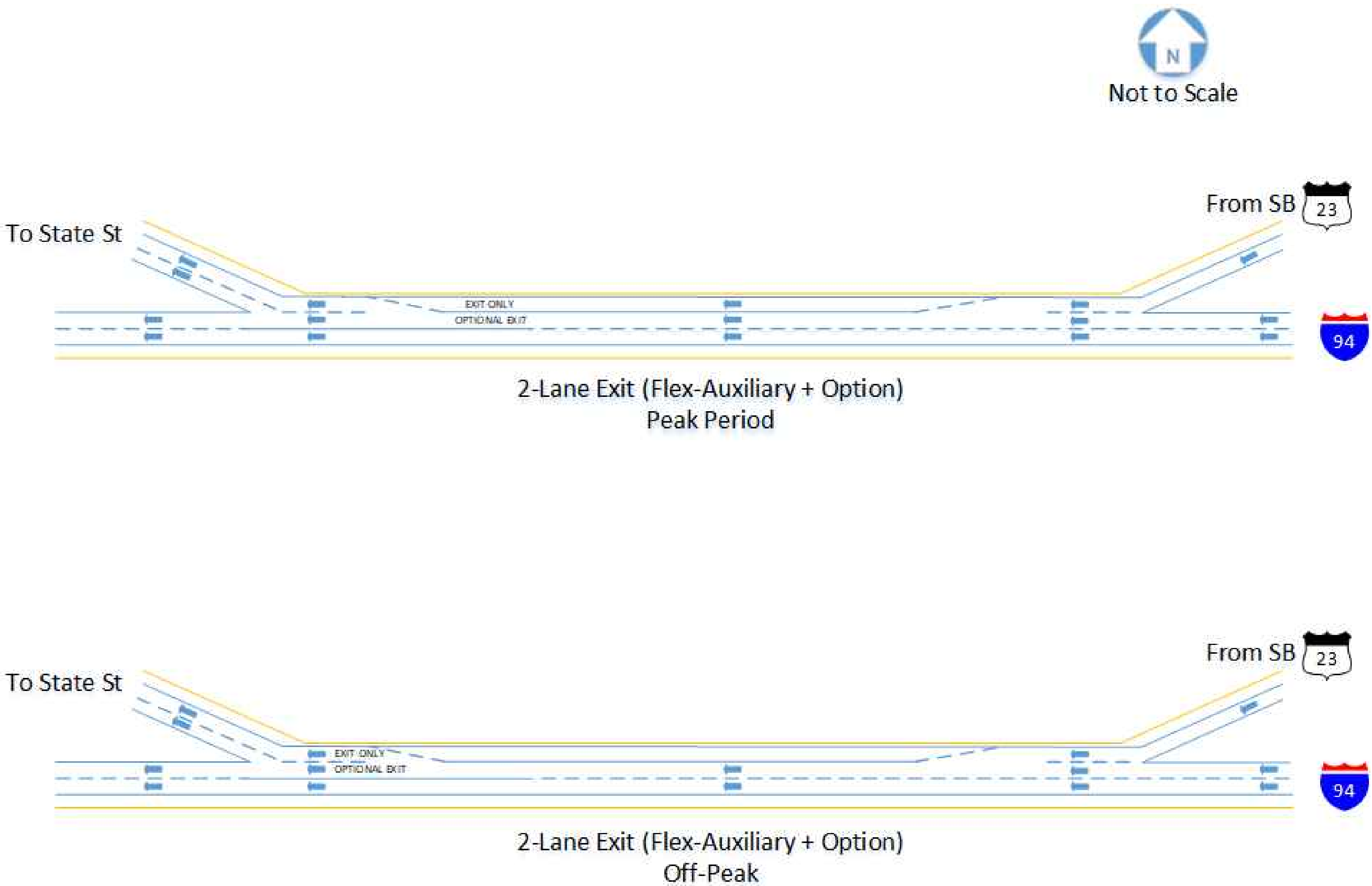



**Figure 20: Concept 2B WB Flex-Auxiliary Lane (Schematic)**

## 4.3 WESTBOUND I-94 TO NORTHBOUND US-23 BOTTLENECK IMPROVEMENT CONCEPTS

Congestion from this existing bottleneck regularly spills back along westbound I-94 for over six miles during the typical AM commuter rush. The westbound I-94 to northbound US-23 movement during this time period is a high-volume movement (approximately 1,200 vehicles during the AM peak hour) in a single lane exit ramp from I-94 that merges with the northbound US-23 collector-distributor (CD) roadway and then the CD roadway merges with mainline US-23 northbound shortly thereafter. These two successive merges in close proximity and the high-volume of ramp traffic during this AM peak is what leads to the severe congestion that spills back along westbound I-94.

The Local Stakeholder Group identified three preliminary build concepts for evaluation in addition to a Future No-Build concept that maintained the existing physical roadway network and served as a base for comparison against the build concepts. The build concepts were as follows and are illustrated in Figure 21 (schematically):

1. ***Acceleration Lane*** – Reconstruct the acceleration lane where the northbound CD road merges with mainline northbound US-23 to lengthen the acceleration lane to just south of the Packard Street structure.
2. ***Dual-Lane WB to NB Exit Ramp*** – Merge the existing northbound CD road with mainline northbound US-23 in advance of the entrance ramp from westbound I-94 and carry a dual-lane westbound to northbound ramp on the existing alignment of the northbound CD roadway.
3. ***Hybrid*** – This concept combines the previous two concepts into a single concept.

### OPERATIONS

An operational review was performed for each of the three concepts using microsimulation (VISSIM). 2045 AM and PM peak period models for each of the three concepts were created by modifying the Future No-Build models to reflect the proposed geometric changes.

Preliminary analysis quickly showed that only the Hybrid concept was effective at resolving the westbound I-94 congestion. As a result, only this concept was advanced for a detailed operational benefits summary.

To determine the operational benefits associated with the Hybrid concept, the following steps were followed:

- Network delay associated with the westbound I-94 to northbound US-23 movement was calculated for each time period (results based on an average of 10 simulation runs).
- The network delay was multiplied by the number of vehicles experiencing the delay to arrive at a total vehicle-hours of delay value for both passenger vehicles and commercial trucks in each time period.
- The AM and PM peak period values were summed together to arrive at an approximated daily vehicle-hours of delay for both passenger vehicles and commercial trucks.
- The daily vehicle-hours of delay for each concept was compared to the daily vehicle-hours of delay for the No-Build with the difference being the operational benefit of that concept.
- The daily operational benefit (veh-hours) for a concept was monetized using assumptions from MDOT's *C&R Benefit Cost Spreadsheet_v2.1.xlsx* to create an annual operational benefit estimate.

Table 19 summarizes the estimated operational benefits associated with the Hybrid concept for the year 2045.

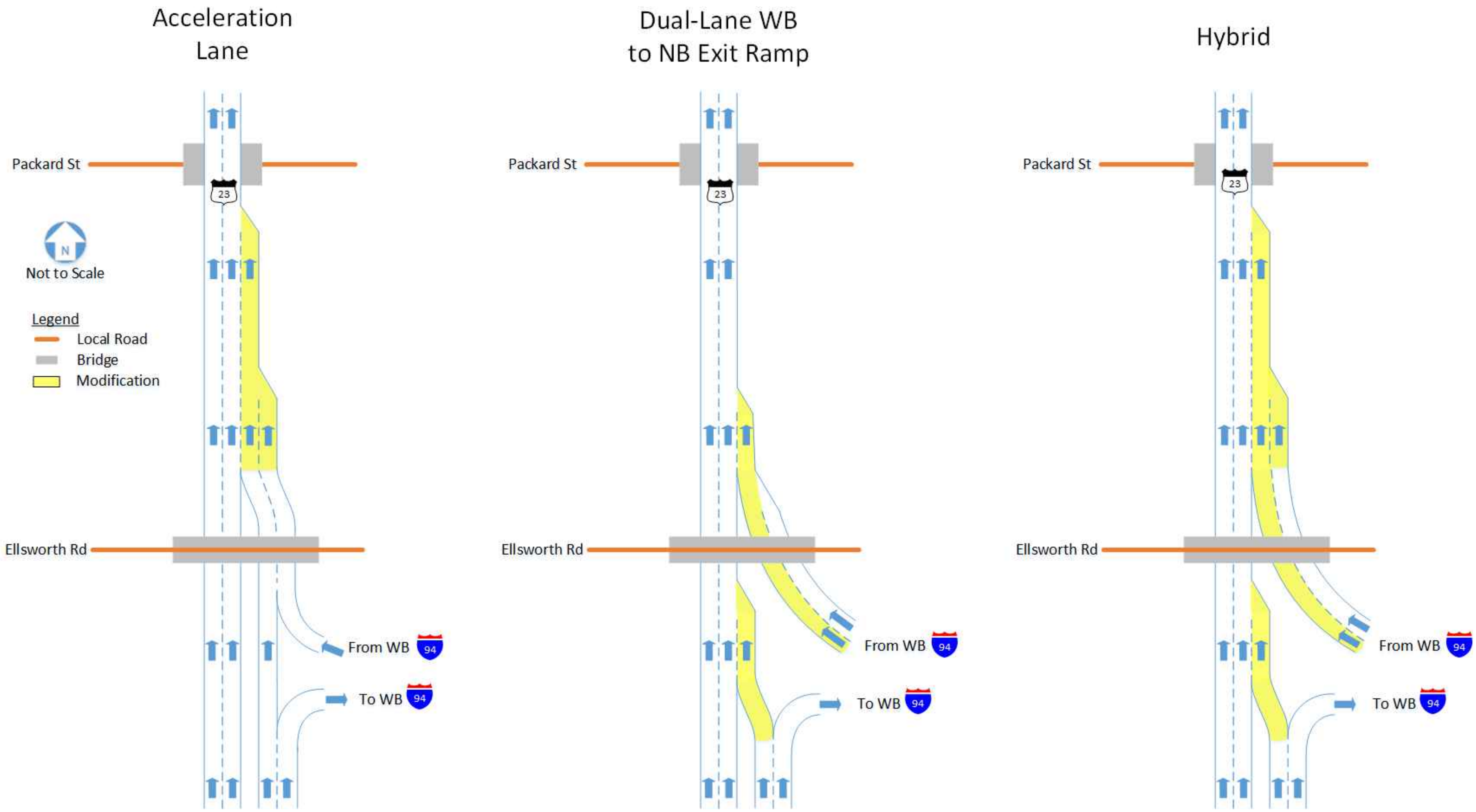



**Figure 21: WB I-94 to NB US-23 Bottleneck Improvement Concepts (Schematic)**

**Table 19: Estimated Operational Benefits of the Hybrid Concept**

| Time Period | Hybrid Concept |
|---|---|
| **Daily** | $32.6 K |
| **Annual** | $8.1 M |

In contrast to the 2045 Future No-Build model, the Hybrid concept clears all congestion along I-94 for the duration of the AM peak. The removal of the I-94 to US-23 bottleneck does result in increased congestion and queueing on northbound US-23. Without any additional capacity improvements to northbound US-23, this congestion shift is the trade-off to achieve improved operations on the larger volume corridor of westbound I-94. The new congestion along northbound US-23 is localized and is estimated to recover before the end of the AM peak period. A comparison between the No-Build and Hybrid concept of average queues along westbound I-94 is provided in Table 20.

**Table 20: Estimated Average Queue Length Comparison along WB I-94 During the AM Peak Period (2045 Future Year)**

| Time | FNB | Hybrid Concept |
|---|---|---|
| | Avg. Queue (ft) | |
| **6:30 - 7:30 AM** | 5,301 | 184 |
| **7:30 - 8:30 AM** | 35,440 | 130 |
| **8:30 - 9:30 AM** | 59,284 | 6 |
| **9:30 - 10:00 AM** | 64,390 | 17 |

## SAFETY

The geometric improvements associated with the Hybrid concept are not readily quantifiable using current HSM methodologies; however, there are qualitative statements regarding safety that can be made. By reducing the congestion and time of congestion along WB I-94 with this concept, the risk of congestion-related crashes would also likely be reduced along WB I-94. There may be some increased risk as some delay is shifted to NB US-23 with this concept, but the congestion along NB US-23 is anticipated to stay localized to the system interchange and recover more quickly than the FNB condition. This localized congestion would appear to be a reasonable tradeoff versus the multi-mile backup on the higher volume WB I-94 that occurs today.

## SUMMARY AND RECOMMENDATIONS

The Hybrid concept is the recommended improvement concept to reduce the congestion associated with the existing WB I-94 to NB US-23 bottleneck. A significant reduction in congestion and queueing along WB I-94 is anticipated with this concept. Table 21 lists the estimated benefit-cost summary for this concept.

**Table 21: WB I-94 to NB US-23 Bottleneck Improvement Concept Analysis Summary**

| Concept | *DE/DV Needed | Construction Cost ($) | Annual Operational Benefit ($) | *B/C | *ROI (years) |
|---|---|---|---|---|---|
| **Hybrid** | 0 | 10.8 M | 8.1 M | 0.76 | 1.3 |

**DE/DV = Design Exception and/or Design Variance*
**B/C = Benefit-Cost ratio (planning level based on 2019 dollars for construction cost and 2045 estimated benefits)*
**ROI = Return on Investment (planning level based on 2019 dollars for construction cost and 2045 estimated benefits)*

The conceptual plan sheet and preliminary cost estimate are found in Appendices F and E, respectively. Some additional design considerations for this concept follow.

***Design Considerations***

- Existing signage on the outside of US-23 may have to be removed, salvaged, and reinstalled to meet MDOT clear zone requirements

**Design Exceptions:**

(None anticipated)

**Design Variances:**

(None anticipated)

**ROW Required:**

(None anticipated)

**Environmental:**

(None anticipated)

## 4.4 WESTBOUND I-94 AT US-23 SYSTEM INTERCHANGE SAFETY IMPROVEMENT CONCEPTS

Westbound I-94 within the US-23 system interchange was identified as a high crash location due to the heavy weaving of merging and diverging traffic along westbound I-94 between the loop ramps to/from US-23.

The Local Stakeholder Group identified three preliminary build concepts for evaluation in addition to a Future No-Build concept that maintained the existing physical roadway network and served as a base for comparison against the build concepts. The build concepts are illustrated (schematically) in Figure 22 and are as follows:

1. ***Westbound Collector-Distributor*** – Construct a new single lane westbound collector-distributor (CD) roadway parallel to westbound I-94 to facilitate weaving between the US-23 loop ramps on a lower volume roadway and mirror the eastbound I-94 CD roadway at US-23 operations.
2. ***Northbound US-23 to Westbound I-94 Flyover Ramp*** – Remove and replace the loop ramp in the northeast quadrant of the interchange with a northbound to westbound flyover ramp eliminating the existing weave areas between the loop ramps along westbound I-94 as well as northbound US-23.
3. ***Westbound I-94 to Southbound US-23 Flyover Ramp*** – Remove and replace the loop ramp in the northwest quadrant of the interchange with a westbound to southbound flyover ramp eliminating the existing weave areas between the loop ramps along westbound I-94 as well as southbound US-23.

Preliminary feedback from MDOT and FHWA on the WB I-94 CD concept was that while this concept is theoretically feasible, it would require extensive reconstruction of the US-23 over I-94 bridge structures and ramps to provide room for the WB CD roadway and ramp tie-ins. This is likely cost-prohibitive compared to the other concepts and not a preferred concept from an operations and safety perspective given it maintains the cloverleaf weave area between loop ramps, albeit on a lower volume CD road. For these reasons, only the flyover concepts were advanced for detailed analysis.

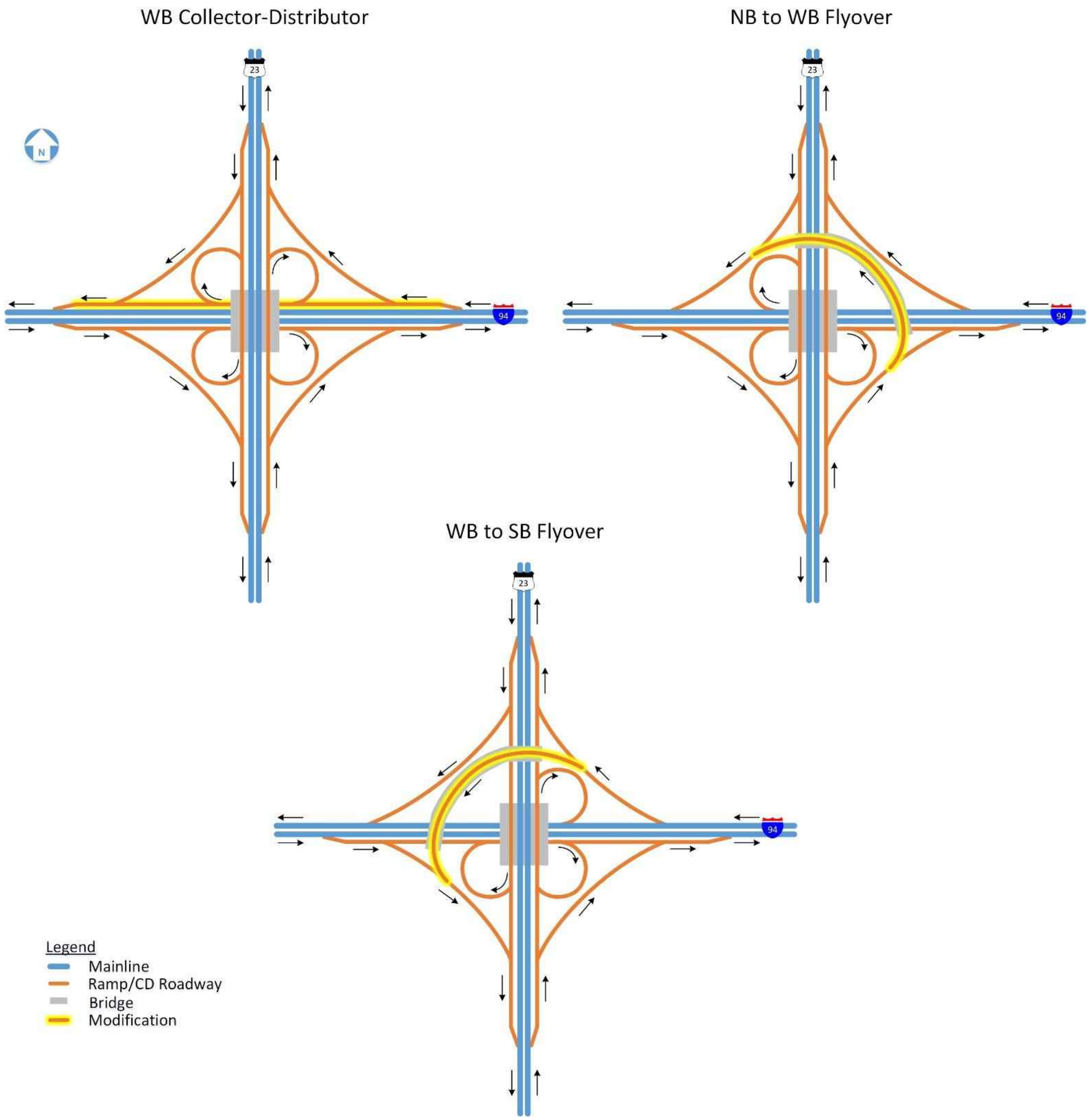



**Figure 22: WB I-94 at US-23 System Interchange Safety Improvement Concepts (Schematic)**

## OPERATIONS

An operational review was performed for each of the flyover concepts using microsimulation (VISSIM). 2045 AM and PM peak period models for each of the three concepts were created by modifying the Future No-Build models to reflect the proposed geometric changes.

To determine the operational benefits associated with the flyover concepts, the following steps were followed:

- Network delay associated with the I-94 at US-23 system interchange was calculated for each time period (results based on an average of 10 simulation runs).
- The network delay was multiplied by the number of vehicles experiencing the delay to arrive at a total vehicle-hours of delay value for both passenger vehicles and commercial trucks in each time period.
- The AM and PM peak period values were summed together to arrive at an approximated daily vehicle-hours of delay for both passenger vehicles and commercial trucks.
- The daily vehicle-hours of delay for each concept was compared to the daily vehicle-hours of delay for the No-Build with the difference being the operational benefit of that concept.
- The daily operational benefit (veh-hours) for a concept was monetized using assumptions from MDOT's *C&R Benefit Cost Spreadsheet_v2.1.xlsx* to create an annual operational benefit estimate.

Table 22 summarizes the estimated relative operational benefits associated with each concept for the year 2045.

**Table 22: Estimated Operational Benefits of Flyover Concepts**

| Time Period | NB to WB Flyover | WB to SB Flyover |
|---|---|---|
| **Daily** | $2.3 K | $3.7 K |
| **Annual** | $584.1 K | $918.6 K |

### SAFETY

A high-level review of the two I-94 flyover ramp concepts was conducted to estimate the potential safety performance of each. Crash data was obtained from the MDOT from 2013 to 2017 within the area of the I-94 and US-23 system interchange. This crash data was pre-processed for use with the Interactive Highway Safety Design Model (IHSDM) software. The IHSDM is a decision support tool which implements the Highway Safety Manual methodology to assess potential changes to the design of a highway. As Michigan specific calibration factors have not yet been developed for the IHSDM, these results provide a relative comparison between the 'before' and 'after' periods. The alternatives considered the interchange as a whole, as the changes to each ramp also impact the I-94 and US-23 mainlines and associated maneuvers (i.e. weaving), resulting in the same number of average annual before crashes for both concepts. The MDOT Time of Return (TOR) form was used to estimate the Annual Benefit (Present Value with Inflation) to ensure that MDOT supplied values were utilized. Table 23 summarizes the estimated relative safety benefits associated with each concept.

**Table 23: Estimated Safety Performance of Flyover Concepts**

| Description | Annual Avg. Before | | Annual Avg. After | | % Reduction | | Est. Annual Benefit |
|---|---|---|---|---|---|---|---|
| | PDO | F&I | PDO | F&I | PDO | F&I | |
| **NB to WB Flyover** | 73.9 | 33.5 | 70.7 | 31.6 | 4.3% | 5.6% | *$931.5 K* |
| **WB to SB Flyover** | 73.9 | 33.5 | 70.7 | 31.7 | 4.3% | 5.4% | *$851.3 K* |

### SUMMARY AND RECOMMENDATIONS

The WB to SB Flyover concept is the recommended improvement concept to improve safety at the system interchange for WB I-94. This concept has the higher benefit-cost ratio when comparing the two flyover concepts, has comparable safety benefits to the NB to WB Flyover concept, and better overall operational benefits. Table 24 lists the estimated benefit-cost summary for this concept. Construction costs are significant for these concepts compared to the estimated operational and safety benefits.

**Table 24: WB I-94 at US-23 Safety Improvement Concept Analysis Summary**

| Concept | *DE/DV Needed | Construction Cost ($) | Annual Operational Benefit ($) | Annual Safety Benefit ($) | *B/C | *ROI (years) |
|---|---|---|---|---|---|---|
| **NB to WB Flyover** | 0 | 38.1 M | 584.1 K | 931.5 K | 0.04 | 25.1 |
| **WB to SB Flyover** | 0 | 29.9 M | 918.6 K | 851.3 K | 0.06 | 16.9 |

**DE/DV = Design Exception and/or Design Variance*
**B/C = Benefit-Cost ratio (planning level based on 2019 dollars for construction cost and 2045 estimated benefits)*
**ROI = Return on Investment (planning level based on 2019 dollars for construction cost and 2045 estimated benefits)*

The conceptual plan sheet and preliminary cost estimate are found in Appendices F and E, resepectively. Some additional design considerations for this concept follow.

***Design Considerations***

- Introduces one new flyover structure
- Design speed of flyover ramp (40 mph) is on the lower range for acceptable design speed in AASHTO. This design speed was selected to fit the flyover ramp within the existing ROW footprint of the interchange. A higher design speed could be used, but would likely require additional ROW.
- May require slope paving reconstruction needed for Carpenter Road bridge

**Design Exceptions:**

(None anticipated)

**Design Variances:**

(None anticipated)

**ROW Required:**

- Potential ROW impacts in southwest quadrant

**Environmental:**

(None anticipated)

# 4.5 STAKEHOLDER AND PUBLIC INVOLVEMENT

*Public Meeting*

A public meeting was held November 7, 2019 at the Courtyard Marriott Hotel in Ann Arbor, MI. The purpose of the public meeting was to present and collect public feedback on the following items:

1. Purpose & Need of the study
2. Existing deficiencies along the study corridor
3. Preliminary improvement concepts

29 people attended this public meeting and a general summary of comments is provided in Appendix G. In early 2020, the COVID 19 pandemic occurred, restricting any further in-person public meetings for this study.

*Online Survey*

A subsequent online survey was sent out as a virtual public involvement (VPI) tool with the comment period left open 11/18/2019 – 12/13/2019 (see Figure 23). The survey communicated similar information as that presented at the public meeting, and just over 1,500 individuals responded and provided feedback. Participants when asked to rate mainline I-94 concepts on a scale of 1 to 5, where 1 is "least preferred" and 5 is "most preferred," were largely in favor of adding an additional travel lane in both directions of I-94 for either the full study limits or portions of the study limits. It was communicated at the time of the public engagement that a third lane on I-94 could take several forms, including conventional widening with full shoulders, re-striping with narrower shoulders, or re-striping and using the shoulder as a travel lane during peak times. A more detailed summary of the online survey findings is presented in Appendix G. The feedback from both the public meeting and online survey was used to refine which alternatives to advance for further study and narrow in on preferred improvement concepts.

*Project Website*

A project website was maintained by MDOT throughout the life of the study for stakeholders and the public to review posted materials and provide feedback via the email contact on the site.


**Figure 23: I-94 Operations Study Online Survey (Sample Screen)**

# 4.6 SUMMARY OF RECOMMENDED IMPROVEMENT CONCEPTS

The previous sections described the improvement concepts developed to address three core issues along the I-94 study corridor:

1. ***I-94 mainline mobility*** – Reduce congestion and improve safety and reliability of the I-94 corridor.
2. ***Westbound I-94 to northbound US-23 bottleneck*** – Reduce the congestion associated with this movement, particularly in the AM commuter rush.
3. ***Westbound I-94 at US-23 system interchange safety*** – Improve safety at this high crash location.

Table 25 provides a summary of the recommended improvement concepts from the previous section and is organized in the order in which they are recommended to be implemented. The order of implementation was determined using microsimulation modeling to address the most critical bottlenecks first with subsequent improvements in the order that would be most visibly recognized as an operational/safety improvement by the public. It is understood that the availability of funds will be a controlling factor for whether an improvement concept gets advanced for design and construction.

**Table 25: Summary of Recommended Improvement Concepts**

| Order | Project Description | Construction Cost ($) | Annual Operational + Safety Benefit ($) | B/C | ROI (years) |
|---|---|---|---|---|---|
| **1** | ***WB I-94 to NB US-23 Improvements*** – Merge the existing NB US-23 CD road with mainline NB US-23 in advance of the entrance ramp from WB I-94 and carry a dual-lane WB to NB ramp on the existing alignment of the NB CD roadway and lengthen acceleration lane to just south of Packard Street | 10.8 M | 8.1 M | 0.76 | 1.3 |
| **2** | ***EB I-94 Flex-Auxiliary 1*** **–** Utilize outside shoulder as a travel lane during peak periods (NB State ramp to EB I-94 CD) and add a right-turn pocket for EB I-94 exit ramp at State Street | 19.0 M | 15.2 M | 0.80 | 1.25 |
| **3** | ***WB I-94 Flex-Auxiliary*** – Utilize outside shoulder as a travel lane during peak periods (SB US-23 on ramp to State) and construct a dual-lane exit for WB I-94 at State Street | 11.1 M | 4.9 M | 0.44 | 2.3 |
| **4** | ***EB I-94 Flex-Auxiliary 2*** - Utilize outside shoulder as a travel lane during peak periods (NB Ann Arbor-Saline on ramp to State Street) | 2.2 M | 2.0 M | 1.0 | 1.0 |
| **5** | ***WB I-94 to SB US-23 Flyover Ramp*** - Remove and replace the loop ramp in the NW quadrant of the interchange with a WB to SB flyover ramp | 29.9 M | 1.8 M | 0.06 | 16.9 |

*B/C = Benefit-Cost ratio (planning level based on 2019 dollars for construction cost and 2045 estimated benefits)*
*ROI = Return on Investment (planning level based on 2019 dollars for construction cost and 2045 estimated benefits)*

Figure 24 graphically illustrates the information from Table 25 to provide a "roadmap" to the recommended improvement concepts.

### MOE SUMMARY

Tables 26 through 30 illustrate the anticipated 2045 MOEs with the improvements in place as noted in Table 25 and compared against the 2045 FNB conditions. The detailed tabular results can be found in Appendix D. In addition to the tabular results, lane schematics were created to report peak hour volume, density, and average travel speed from the VISSIM models down to the individual travel lanes within the study area. Examples of these lane schematics are shown in Figure 25Figure 25: Future No-Build (2045) and Build (2045) Lane Schematic MOE Summary (AM Peak Hour) Example and Figure 26. Full lane schematic summaries for the for the Existing and Future No-Build conditions are found in Appendix D.

It should be noted that as part of this I-94 Operations Study, certain capacity improvements were assumed in the future conditions so that bottlenecks along US-23 were alleviated and the full traffic demand could get to and from I-94 when testing improvement concepts along I-94. These assumed improvements were only for purposes of this study, and it is recommended a detailed study of the US-23 corridor be conducted to identify a strategic set of improvements to address the mobility issues that exist today and are anticipated in 2045. The improvements assumed for the purpose of this study outside of the recommended improvement concepts included:

- Addition of SB US-23 auxiliary lane from Washtenaw Avenue entrance to SB US-23 CD exit (dual-lane exit assumed with auxiliary lane and an option lane)
- Addition of SB US-23 auxiliary lane from SB US-23 CD entrance to Michigan Avenue exit
- Addition of NB US-23 auxiliary lane from US-12 (Michigan Avenue entrance to NB US-23 CD exit)

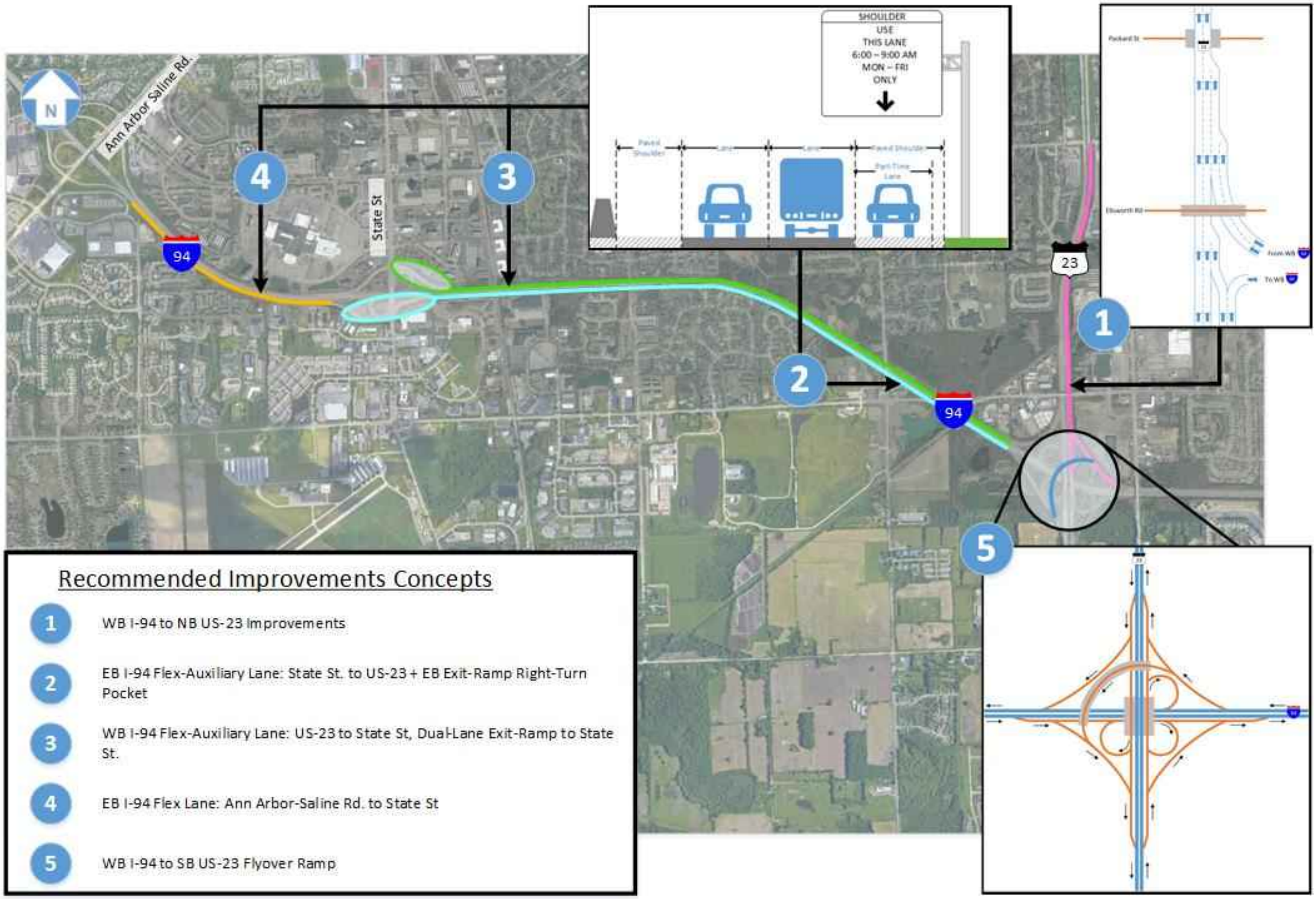



**Figure 24: Recommended Improvement Concepts Map**

**Table 26: Future No-Build (2045) & Build (2045) Freeway Level of Service Results – I-94 EB Peak Hour**

| I-94 Eastbound Segment | Type | AM LOS | | PM LOS | |
|---|---|---|---|---|---|
| | | FNB | Build | FNB | Build |
| I-94 EB | basic | D | D | E | B |
| Ann Arbor-Saline Rd Off Ramp | diverge | F | C | F | B |
| I-94 EB | basic | E | C | F | B |
| Ann Arbor-Saline Rd SB On Ramp | merge | F | C | F | B |
| I-94 EB | basic | F | D | F | B |
| Ann Arbor-Saline Rd NB On Ramp/State St Off Ramp | Weave | na | C | na | B |
| Ann Arbor-Saline Rd NB On Ramp | merge | F | na | F | na |
| I-94 EB | basic | D | na | F | na |
| State St Off Ramp | diverge | C | na | F | na |
| I-94 EB | basic | D | C | F | B |
| State St SB On Ramp | merge | F | C | F | C |
| I-94 EB | basic | F | D | F | D |
| State St NB On Ramp | merge | F | C | F | C |
| I-94 EB | basic | D | C | D | C |
| US-23 Off Ramp | diverge | D | C | D | D |
| I-94 EB | basic | C | C | C | D |
| US-23 On Ramp | merge | C | C | C | F |
| I-94 EB | basic | C | C | C | E |
| US-12 (Michigan Ave) Off Ramp | diverge | C | C | C | F |
| I-94 EB | basic | C | C | C | F |
| US-12 (Michigan Ave) SB On Ramp | merge | C | C | C | F |
| I-94 EB | basic | C | C | D | F |
| US-12 (Michigan Ave) NB On Ramp | merge | D | D | D | F |
| I-94 EB | basic | D | D | D | E |
| Huron St Off Ramp | diverge | C | C | F | D |
| I-94 EB | basic | C | C | D | D |
| Huron St SB On Ramp | merge | C | C | C | D |
| I-94 EB | basic | D | D | D | D |
| Huron St NB On Ramp | merge | D | D | D | D |
| I-94 EB | basic | D | D | D | D |
| US-12 (Michigan Ave) Off Ramp | diverge | D | D | D | F |
| I-94 EB | basic | C | C | C | D |

| I-94 Eastbound Collector-Distributor Segment | Type | AM LOS | | PM LOS | |
|---|---|---|---|---|---|
| | | FNB | Build | FNB | Build |
| US-23 Distributor | basic | D | D | C | D |
| US-23 SB Off Ramp | diverge | C | C | B | C |
| US-23 Distributor | basic | D | E | A | B |
| US-23 SB On Ramp/US-23 NB Off Ramp | weave | F | F | C | C |
| US-23 Collector | basic | C | C | C | D |
| US-23 NB On Ramp | merge | C | C | C | D |

- EB I-94 PM Peak: The removal of the State Street bottleneck with the flex-auxiliary lane and with some assumed capacity improvements along SB US-23, a new bottleneck could potentially develop along EB I-94 near US-12 (Michigan Avenue).

**Table 27: Future No-Build (2045) & Build (2045) Freeway Level of Service Results – I-94 WB Peak Hour**

| I-94 Westbound | Type | AM LOS | | PM LOS | |
|---|---|---|---|---|---|
| Segment | | FNB | Build | FNB | Build |
| I-94 WB | basic | D | C | C | C |
| US-12 (Michigan Ave) On Ramp | merge | F | C | C | C |
| I-94 WB | basic | F | D | D | D |
| Huron St Off Ramp | diverge | F | C | D | D |
| I-94 WB | basic | F | C | C | C |
| Huron St NB On Ramp | merge | F | C | C | C |
| I-94 WB | basic | F | C | C | C |
| Huron St SB On Ramp | merge | F | C | C | C |
| I-94 WB | basic | F | D | D | D |
| US-12 (Michigan Ave) NB Off Ramp | diverge | F | D | D | D |
| I-94 WB | basic | F | D | D | D |
| US-12 (Michigan Ave) SB Off Ramp | diverge | F | C | C | C |
| I-94 WB | basic | F | C | C | C |
| US-12 (Michigan Ave) On Ramp/US-23 NB Off Ramp | weave | na | F | na | C |
| US-12 (Michigan Ave) On Ramp | merge | F | na | C | na |
| US-23 NB Off Ramp | basic | F | na | D | na |
| I-94 WB | basic | B | C | D | C |
| US-23 NB On Ramp | Merge | na | C | na | C |
| US-23 NB On Ramp/US-23 SB Off Ramp | weave | B | na | D | na |
| I-94 WB | basic | B | D | D | C |
| US-23 SB On Ramp | merge | B | C | D | C |
| I-94 WB | basic | C | C | D | C |
| State St Off Ramp | diverge | B | C | C | C |
| I-94 WB | basic | A | B | C | C |
| State St NB On Ramp | merge | B | B | C | C |
| I-94 WB | basic | B | C | C | D |
| State St SB On Ramp | merge | B | B | D | D |
| I-94 WB | basic | B | C | D | D |
| Ann Arbor-Saline Rd Off Ramp | diverge | B | B | C | D |
| I-94 WB | basic | A | B | C | C |
| Ann Arbor-Saline Rd On Ramp | merge | B | B | C | C |
| I-94 WB | basic | B | B | D | D |

- WB I-94 PM Peak:Slight decreases in LOS during the PM Peak along WB I-94 near State Street is due to increased volume served due to the assumed capacity improvements along US-23.

Table 28: Surface Street LOS Results – FNB (2045) and Future Build (2045)

| Intersection | LOS (delay/veh) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | AM | | | | PM | | | |
| | FNB | | Build | | FNB | | Build | |
| AA Saline and EB 94 | 79.1 | E | 74.2 | E | 48.0 | D | 32.5 | C |
| AA Saline and WB 94 | 26.0 | C | 29.1 | C | 62.4 | E | 64.5 | E |
| State and EB 94 | 41.5 | D | 22.2 | C | 155.7 | F | 20.8 | C |
| State and WB 94 | 25.1 | C | 62.3 | E | 30.9 | C | 32.2 | C |

- The intersection of State St and WB I-94 is anticipated to operate at a LOS E in the Build condition compared to a LOS C in the FNB. The AM Peak congestion occurring on WB I-94 in the FNB model meters traffic downstream to State St and results in the better LOS. By removing the upstream bottleneck, more demand is now able to reach this intersection, and is the reason for the degraded LOS in the Build condition.

Table 29: Surface Street Queue Results –Future No-Build 2045 and Build 2045 (AM Peak Hour)

| Intersection | FNB: AM Peak Hour | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Queue Length (ft) | | | | | | | |
| | NB | | SB | | EB | | WB | |
| | Avg | Max | Avg | Max | Avg | Max | Avg | Max |
| **AA Saline and EB 94** | 154 | 838 | 3 | 105 | 23 | 158 | - | - |
| **AA Saline and WB 94** | 38 | 386 | 16 | 239 | - | - | 34 | 251 |
| **State and EB 94** | - | - | 40 | 344 | 129 | 1194 | - | - |
| **State and WB 94** | 76 | 609 | - | - | - | - | 115 | 679 |
| **Intersection** | **Build: AM Peak Hour** | | | | | | | |
| **AA Saline and EB 94** | 13 | 224 | 4 | 97 | 24 | 169 | - | - |
| **AA Saline and WB 94** | 48 | 352 | 17 | 244 | - | - | 60 | 335 |
| **State and EB 94** | - | - | 51 | 539 | 106 | 534 | 0 | 0 |
| **State and WB 94** | 242 | 901 | - | - | - | - | 514 | 1657 |

- The increased westbound queue at the intersection of State St and WB I-94 is directly correlated to the increased volume served due to the removal of the upstream bottlenecks. The additional WB I-94 off ramp lane is anticipated to mitigate the max queue which is not exceeding the storage present on the ramp.

**Table 30: Surface Street Queue Results –Future No-Build 2045 and Build 2045 (PM Peak Hour)**

| Intersection | FNB: PM Peak Hour | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Queue Length (ft) | | | | | | | |
| | NB | | SB | | EB | | WB | |
| | Avg | Max | Avg | Max | Avg | Max | Avg | Max |
| **AA Saline and EB 94** | 8 | 224 | 27 | 408 | 22 | 202 | - | - |
| **AA Saline and WB 94** | 23 | 248 | 534 | 1390 | - | - | 46 | 220 |
| **State and EB 94** | - | - | 2036 | 2677 | 49 | 305 | - | - |
| **State and WB 94** | 57 | 372 | - | - | - | - | 139 | 589 |
| **Intersection** | **Build: PM Peak Hour** | | | | | | | |
| **AA Saline and EB 94** | 11 | 248 | 59 | 626 | 29 | 226 | - | - |
| **AA Saline and WB 94** | 29 | 290 | 558 | 1390 | - | - | 51 | 221 |
| **State and EB 94** | - | - | 50 | 605 | 59 | 295 | 0 | 0 |
| **State and WB 94** | 57 | 482 | - | - | - | - | 206 | 604 |

- At the intersection of State and EB I-94, the addition of the right-turn pocket is expected to assist in reducing the EB approach queue from 2,677 ft to 605 ft (max queue).

# Westbound I-94

**Time: AM Peak**

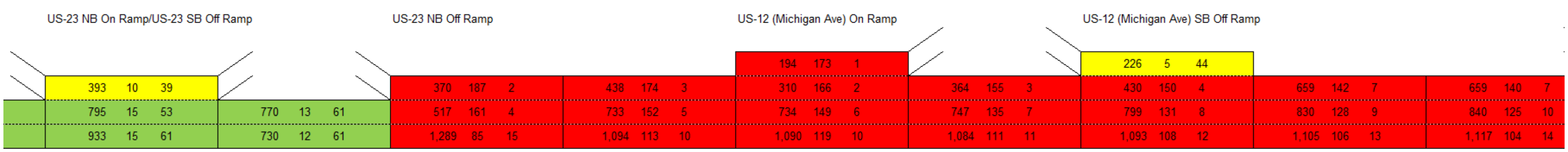
# VISSIM OUTPUT: Volume, Density and Speed

**Legend**

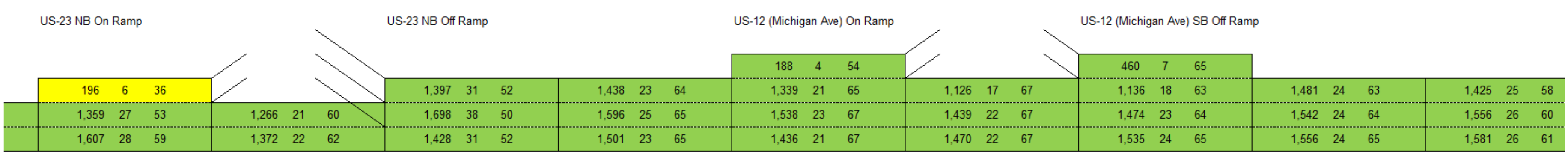
| Volume (veh/ln/hr) | Density (veh/ln/mi/hr) | Speed (mph) |
|---|---|---|
| xxxx | xx | xx |
| xxxx | xx | xx |
| xxxx | xx | xx |

| Speed Thresholds |
|---|
| > 45 |
| 35 to 45 |
| 25 to 35 |
| 0 to 25 |

**Travel Direction: Westbound**




Future No-Build (2045)




Build (2045)

**Figure 25: Future No-Build (2045) and Build (2045) Lane Schematic MOE Summary (AM Peak Hour) Example**

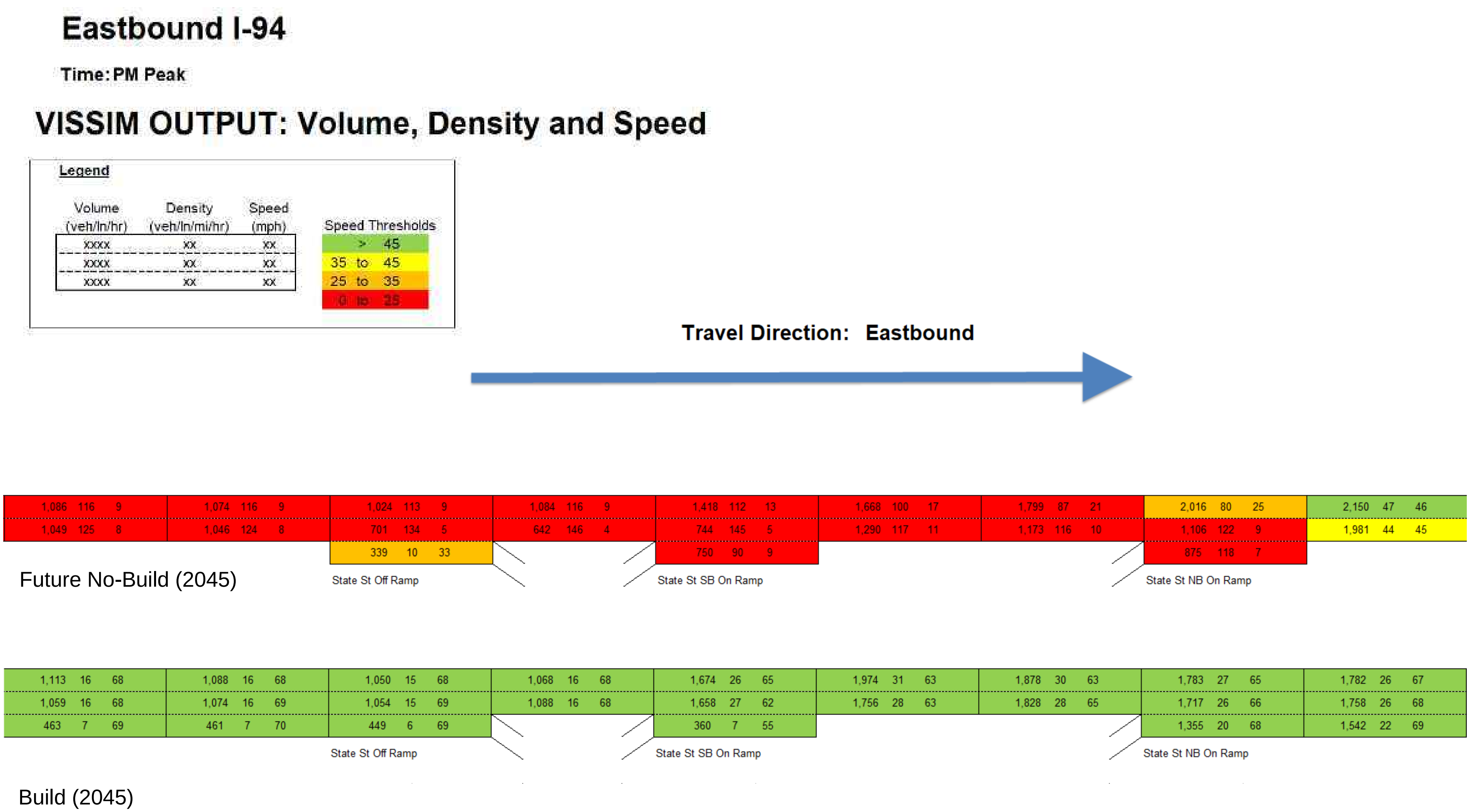



**Figure 26: Future No-Build (2045) and Build (2045) Lane Schematic MOE Summary (PM Peak Hour) Example**

# 5 ITEMS FOR FURTHER CONSIDERATION

Once funding is identified, MDOT will conduct additional Early Preliminary Engineering and Preliminary Engineering activities including completing the Metropolitan Planning Organization, environmental clearance, and design processes. The following are additional items for consideration based on the findings of this study:

### FURTHER STUDY

- US-23: While the focus of this study was identifying concepts to improve operations, safety, and reliability along I-94, US-23 is also heavily congested during peak periods and additional study of this corridor from US-12 to M-14 is recommended for consideration. As part of this I-94 Operations Study, certain capacity improvements were assumed in the future conditions so that bottlenecks along US-23 were alleviated and the full traffic demand could get to and from I-94 when testing improvement concepts along I-94. These assumed improvements were just for the purpose of this study, and again, a more detailed study of the US-23 corridor is recommended to identify a strategic set of improvements to address the mobility issues that exist today. The improvements assumed for the purpose of this study outside of the recommended improvement concepts included:
  - Addition of SB US-23 auxiliary lane from Washtenaw Avenue entrance to SB US-23 CD exit (dual-lane exit assumed with auxiliary lane and an option lane)
  - Addition of SB US-23 auxiliary lane from SB US-23 CD entrance to Michigan Avenue exit
  - Addition of NB US-23 auxiliary lane from US-12 (Michigan Avenue entrance to NB US-23 CD exit)
- I-94/Ann Arbor-Saline and I-94/State Street Interchanges: The minimum improvements necessary to keep the interchange ramp terminals from backing up and impacting mainline I-94 were recommended as improvement concepts. This included a dual-lane exit from WB I-94 to State Street and the addition of a right-turn pocket on the EB I-94 ramp terminal at State Street. Individual movements with failing levels of service do remain that may warrant additional study of these interchanges to improve overall mobility and safety.
- Noise Abatement: A noise analysis will be required during final design to determine locations and heights of noise abatement walls that may be warranted
- I-94 East of US-23: Microsimulation analysis indicated that in the 2045 PM peak period, EB I-94 traffic may become congested to a failing LOS F near the interchange with US-12 (Michigan Avenue) which could spill back to the system interchange at US-23. This condition is contingent on both the EB I-94 bottleneck at State Street being removed with the flex-auxiliary lane improvement concept, and SB US-23 congestion removed with some capacity improvements to be determined in a future study as noted above. This congestion along EB I-94 may or may not arise by 2045, so it is recommended that this area continue to be monitored and a study be conducted for potential improvements if operating conditions deteriorate significantly.
- Flex Lane Concept of Operations (ConOps): Should the flex-auxiliary lanes be advanced for design, it is recommended a concept of operations study be conducted to specify how these lanes are to be operated, who will be allowed to use them, and under what conditions. It may be desirable for Bus-on-Shoulder operations to be allowed outside of the peak periods. While it was assumed static signage would specify operational hours for the purpose of this study, dynamic signage could increase functionality and use cases of the flex lane (incident management or special events such as University of Michigan football games). This would be an additional cost that could be determined during the ConOps study if this additional functionality was warranted.