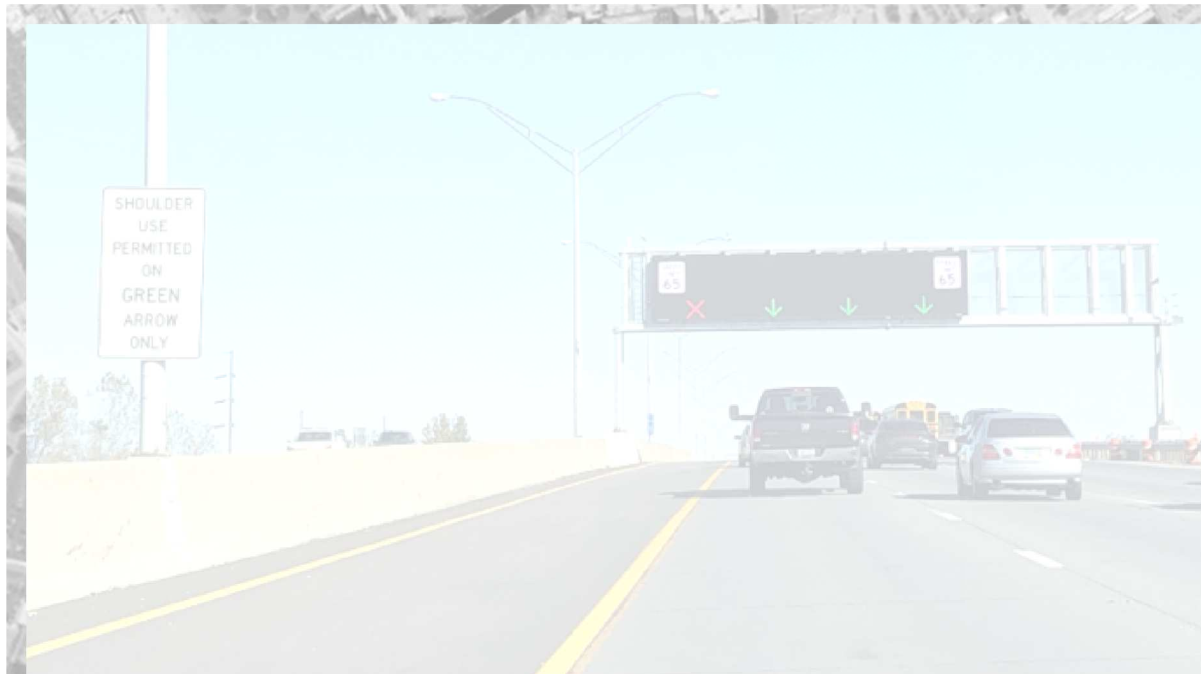

I-90 WB SmartLane Corridor Study
Cleveland, Ohio

Feasibility Study
January 21, 2022

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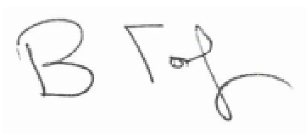

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CHAPTER 1: EXECUTIVE SUMMARY

I-90 WB experiences significant daily congestion during the PM peak period of 4-7pm from East of 55th Street through the Innerbelt Curve and Innerbelt Trench to I-77. This is resulting in a lot of rear-end and sideswipe passing crashes, generally associated with congested conditions. As part of this study, short-term, low-cost capacity improvements were evaluated to add capacity through this corridor. These improvements included the addition of a SmartLane, like what was constructed recently along I-670 EB from downtown Columbus to the I-270 outerbelt. SmartLane is the ODOT-named initiative of using the shoulder as a part-time lane to address congestion concerns. The shoulder is used as a lane during peak periods of congestion when needed, then returned to a shoulder during non-peak periods of congestion. Changeable message boards are used to communicate to drivers when it is appropriate to use the part-time shoulder lane and typically numerous cameras are placed along the corridor to allow for operators to monitor the SmartLane corridor remotely for any obstructions that may be in the shoulder lane. While these improvements may appear to be short term, there is not a commitment to the long-term improvements at this time because of the uncertainty of available funding for future construction projects that are expected to significantly change the alignment and proposed typical section of I-90 through the Innerbelt Trench (East 22nd Street to the SR 2 interchange) and Innerbelt Curve (SR 2 interchange). It is also possible that the improvements specified as part of this study could greatly improve traffic flow and wayfinding during construction of the future construction projects.

Two Build SmartLane alternatives, developed to improve the congestion and the safety performance through this section of I-90 WB, were evaluated. Both alternatives utilized an inside (left side) SmartLane by shifting the general-purpose lanes to the outside then starting the SmartLane on the inside. The difference between the two Build alternatives is where the SmartLane begins. **Alternative 1** (*West of SR 2 Start*) begins the SmartLane west of the entrance ramp from SR 2 EB. This alternative maintains the existing two lanes along I-90 WB through the SR 2 interchange. **Alternative 2** (*East of SR 2 Start*) begins the SmartLane east of the SR 2 interchange between East 55th Street and SR 2. This alternative adds an additional lane of capacity through the SR 2 interchange.

An Evaluation Matrix is included in this report that summarizes graphically the comparative analysis between the two Build alternatives. Each alternative was compared based on the following categories:

- Safety Performance
- Traffic Operations
- Adherence to Geometric Standards
- Construction Cost

A construction cost estimate was prepared for the two Build alternatives.

The purpose of the study is to identify alternatives that reduce the congestion along the I-90 WB corridor from the SR 2 interchange to the I-77 interchange. Based on the results of the analysis and what is shown in the Evaluation Matrix, both alternatives show a noticeable benefit over the *No-Build* alternative with respect to safety performance. The total crash frequency decreased in every severity type for both Build alternatives. However, *Alternative 2* shows significantly better results than *Alternative 1* because it alleviates the congestion at the major bottleneck in the corridor, the SR 2 interchange. It reduces the predicted crash frequency of the fatal, serious injury, minor injury and possible injury crashes. For this reason, *Alternative 2* scores the best in this category.

With respect to Traffic Operations, the biggest capacity constraint in the I-90 WB corridor is the two-lane mainline segment through the SR 2 interchange. Starting the SmartLane east of this interchange (*Alternative 2*) will provide an additional lane through this pinch point and provide a significant improvement in operations for the entire corridor. Starting the SmartLane west of the interchange (*Alternative 1*) will not provide any benefit to the pinch point and ultimately provides very little benefit to the rest of the corridor. The capacity analysis shows that any improvement for the corridor needs to address the capacity through the SR 2 interchange. For this reason, *Alternative 2* performs considerably better than *Alternative 1*.

Both Build alternatives were compared based on their ability to adhere to geometric standards. Several sub criteria were evaluated, including lane and shoulder width, horizontal stopping sight distance (HSSD), vertical clearance, lateral clearance, and interchange ramp geometry. The two Build alternatives have the same function, proposed typical section, and footprint west of SR 2. The difference between these two alternatives in this category is isolated to the SR 2 interchange. With the narrow opening under the existing SR 2 bridge over I-90, *Alternative 2* creates additional impacts due to reduced vertical clearance, lateral clearance, and HSSD through this curve and under this bridge than *Alternative 1*. For this reason, *Alternative 1* scores better than *Alternative 2.*

The estimated construction cost *Alternative 1* is $9.92M and for *Alternative 2* is $13.79M in 2025 construction dollars. While *Alternative 2* is estimated to cost nearly $4M more than *Alternative 1*, the capacity and safety benefits of introducing the additional I-90 WB lane through the SR 2 interchange make that additional cost valuable, as shown by the minimal capacity benefit *Alternative 1* has over the *No-Build* alternative and the significant capacity and safety improvement *Alternative 2* has over *Alternative 1.*

An Evaluation Matrix is included in this report and shown in ***Figure 1*** that summarizes graphically the comparative analysis between all the alternatives.

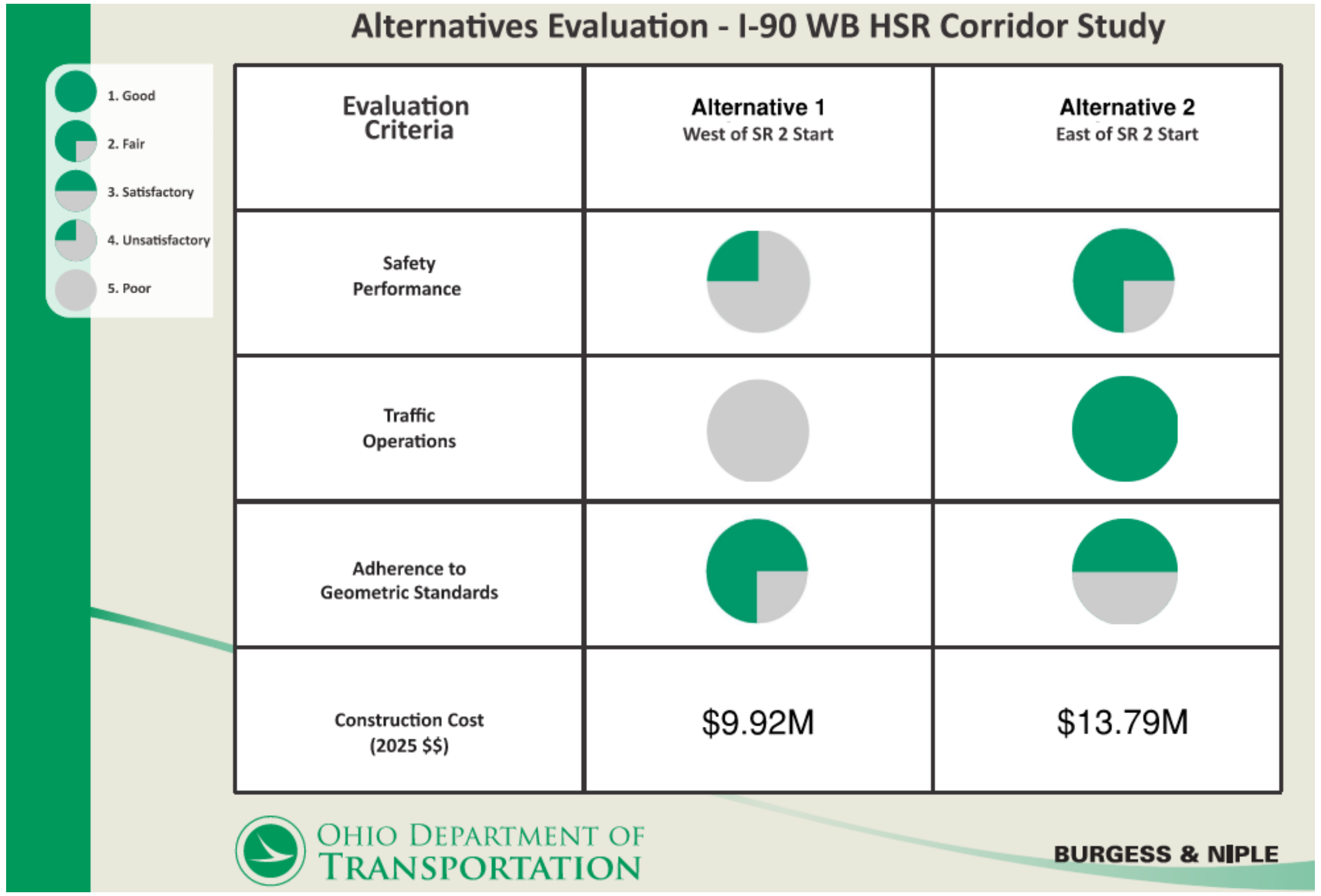

Figure 1 – Evaluation Matrix

Upon review of the Build alternatives, *Alternative 2* is the highest performing alternative with respect to capacity improvement and safety performance. This alternative addresses the capacity bottleneck that exists through the I-90 WB corridor at the SR 2 interchange. Due to its ability to reduce the congestion and improve the safety performance through the corridor, ***Alternative 2* is determined to be the Recommended Alternative to carry forward into the next phase of project development based on the analysis completed as part of this study**.

CHAPTER 2: INTRODUCTION

<u>**Existing Conditions**</u>**:** Planned in the 1940s and built during the 1950s and early 1960s, the Cleveland Innerbelt was designed to move traffic around the south side of downtown, shown in ***Figure 2***. It was also intended to complement two existing freeways built in the 1930s and 1940s – Memorial Shoreway (SR 2) and the Willow Freeway (I-77). The Memorial Shoreway extended 10 miles along Cleveland's lakefront north of the Central Business District (CBD) between Edgewater Park and Gordon Park. The Willow Freeway stretched along the eastside to the city of Independence in southern Cuyahoga County. The Innerbelt was designed to connect to Memorial Shoreway near East 30th Street, join with the Willow Freeway on the south side of downtown, and also link to a future freeway across the Cuyahoga River Valley to provide access to Cleveland Hopkins International Airport and points south.

Figure 2 – Cleveland Innerbelt Overview Map

The Cleveland Innerbelt is a high capacity, limited-access interstate highway extending from Cleveland's Tremont neighborhood on the West Side of the Cuyahoga River, across the Cuyahoga Valley, around the southern and eastern edges of downtown to the City's lakefront district at Burke Lakefront Airport. The Innerbelt is an important segment of the federally designated interstate highway system that crosses the United States to provide efficient movement of industrial goods and to link major metropolitan centers. The Innerbelt is designated as Interstate 90 (I-90) and serves as the northern terminus for two others, Interstate 71 (I-71) and Interstate 77 (I-77).

Reconstruction of the Innerbelt was considered by the Ohio Department of Transportation (ODOT) in the late 1990s. A major planning effort, named the Cleveland Innerbelt Study, was launched by ODOT and the greater Cleveland community in 2000. In that study, the Innerbelt was split into several different segments where potential improvements were identified, shown in ***Figure 3***:

- *Innerbelt Curve* – The Innerbelt Curve is the study's northern-most section, near Burke Lakefront Airport and Lake Erie. The Innerbelt Curve section consists of a fully directional system interchange between I-90 and SR 2. South of the I-90/SR 2 interchange is the Lakeside Avenue interchange, where access is available from I-90 EB and to I-90 WB. South of the Lakeside Avenue interchange is the Superior Avenue interchange. This interchange provides full access to Superior Avenue, via East 26th Street for I-90 WB, and to the Central Business District (CBD) from both I-90 EB and I-90 WB.
- *Innerbelt Trench* – The Innerbelt Trench section is located immediately south of the Innerbelt Curve section and consists of I-90 from Superior Avenue, through the Carnegie Curve, and to approximately East 22nd Street. This section of I-90 is trenched, depressed and bordered by walls or slopes on both sides, with the adjacent streets and surrounding neighborhoods at an elevation above the freeway.
- *Central Interchange* – The Central Interchange section is located south of the Innerbelt Trench section between East 22nd Street the Cuyahoga River. It includes the major system interchange of I-90 and I-77, which connects these two freeways to the local street system at interchanges with Ontario Street/Orange Avenue, East 9th Street, East 14th Street, and East 22nd Street.
- *Central Viaduct* – The Central Viaduct is located south of the Central Interchange and is the primary crossing over the Cuyahoga River, moving interstate traffic from the south (I-71) and west (I-90) across the river to the downtown distribution system of the Central Interchange. I-90 EB and I-90 WB travel across the river on separate twin bridge structures.
- *Southern Innerbelt* – The Southern Innerbelt section is located south of the Central Interchange and Central Viaduct and consists of I-71 from just north of the Fulton Road/West 25th Street to just north of the I-71/I-90/I-490 interchange.

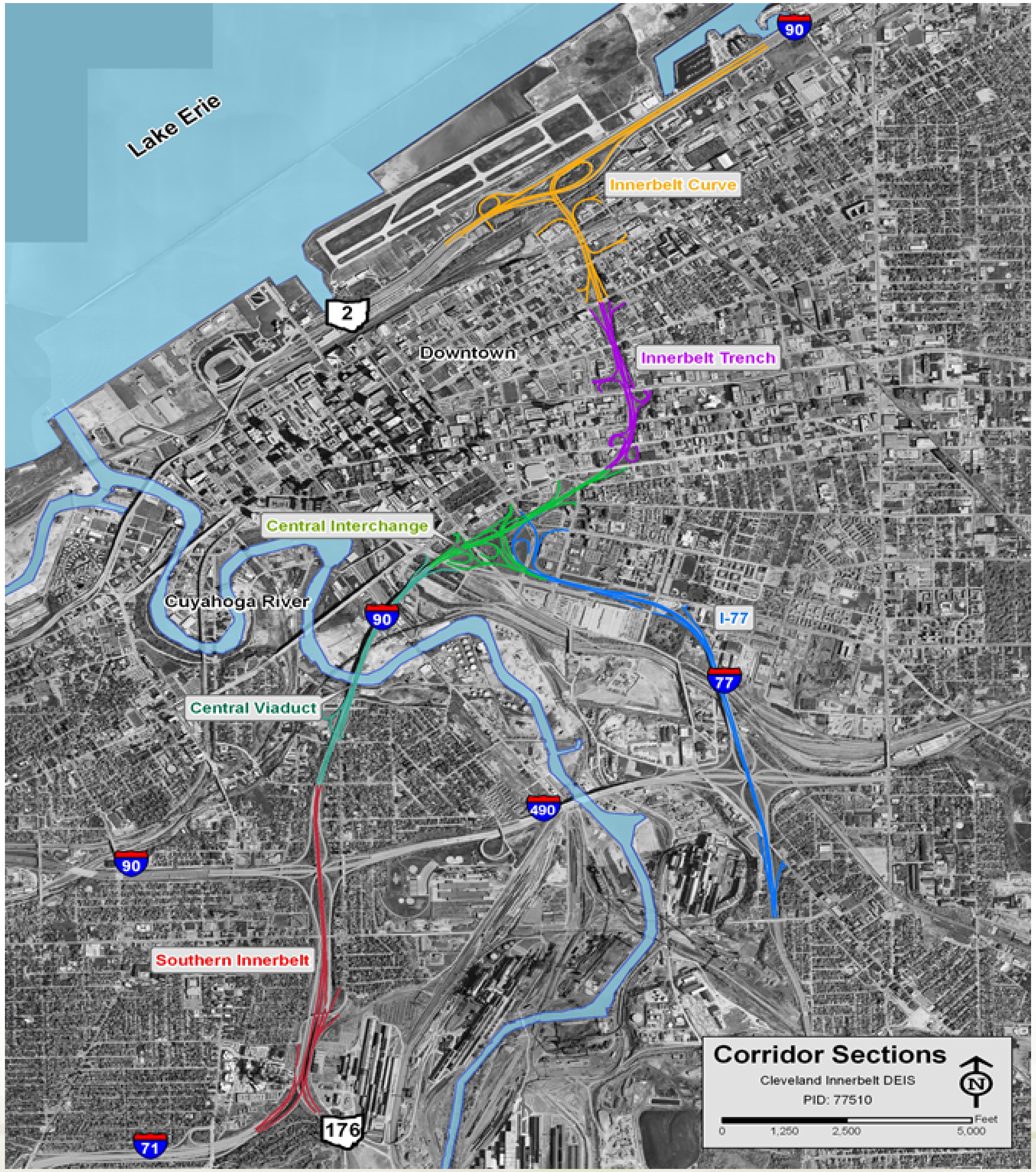

Figure 3 – Study Area map

This I-90 WB SmartLane study focuses on I-90 WB through the Innerbelt Curve and Innerbelt Trench segments of the Innerbelt Corridor. I-90 WB experiences significant daily congestion during the PM peak period of 4-7pm from East of 55th Street through the Innerbelt Curve and Innerbelt Trench to I-77. This is resulting in a lot of rear-end and sideswipe passing crashes, generally associated with congested conditions.

The existing lane configuration of I-90 WB is four lanes between East 55th and SR 2, two lanes through the SR 2 interchange, four lanes between SR 2 and Superior Avenue, three lanes through the Superior interchange, four lanes between the Superior interchange and the Chester interchange, four lanes between the Chester interchange and the Prospect interchange, and three lanes between the Prospect interchange and the interchange with I-77. ***Figure 4*** shows the lane configuration of I-90 through the SR 2 interchange on the north end of this project area and ***Figure 5*** shows the lane configuration of I-90 from Prospect Avenue to East 22nd Street on the south end of this project area. With several service interchanges in this approximately 1.6-mile segment of I-90 between the SR 2 and I-77 interchanges, there are several areas of auxiliary lanes as ramps enter then exit at the next interchange.

Figure 4 – I-90 through the SR 2 interchange

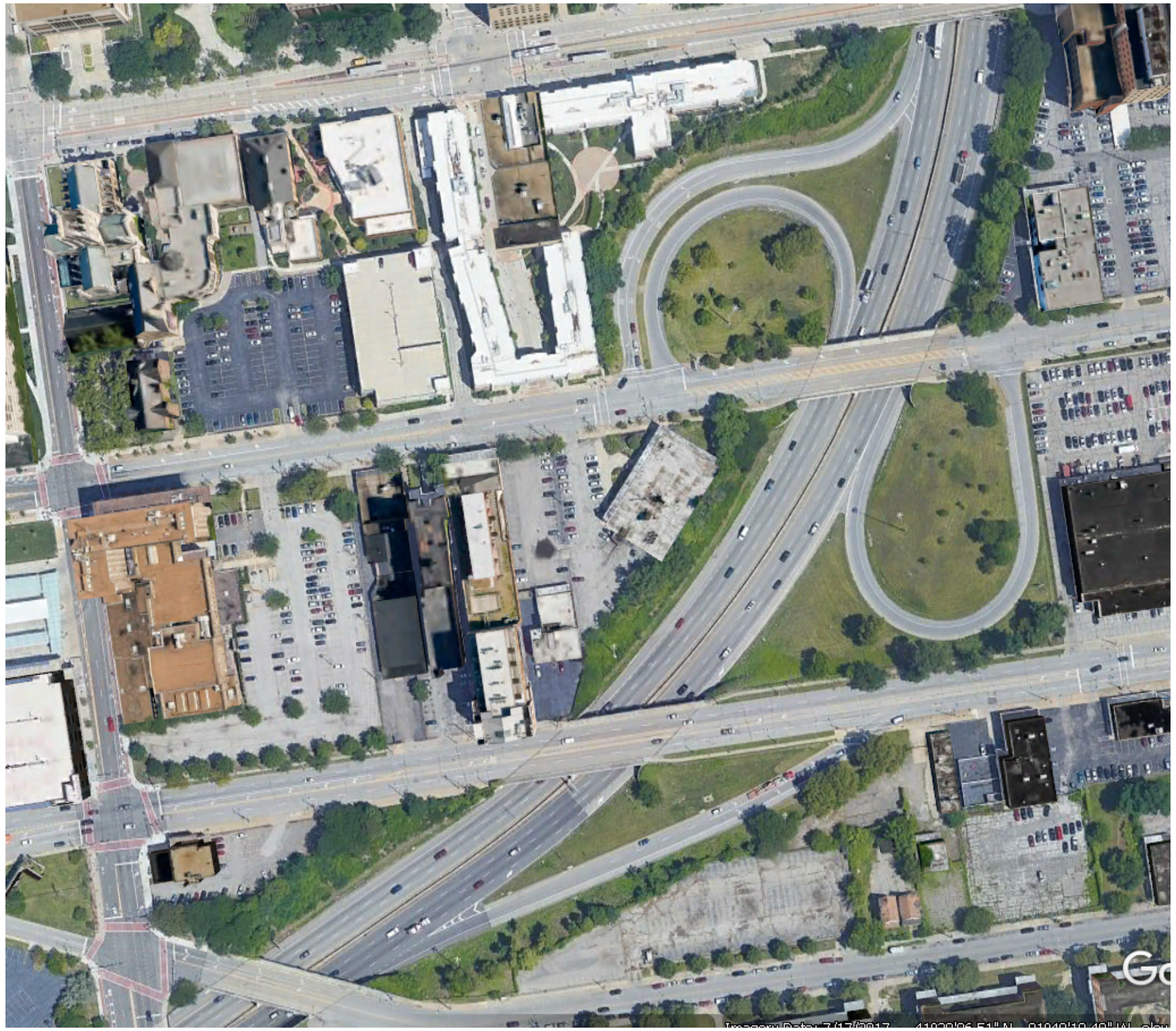

Figure 5 – I-90 between Prospect Avenue and East 22nd Street

The existing typical section of I-90 WB utilizes 12-foot wide travel lanes. The left (median) shoulder is 4.5 feet wide and the right (outside) shoulder is 8 feet wide from SR 2 to Superior Avenue and 10 feet wide from Superior Avenue to East 22nd Street. In the tangent sections, the entire pavement width, including the left shoulder, slopes away from the median toward the outside. ***Figure 6*** shows the existing normal crown typical section for I-90 WB through this section.

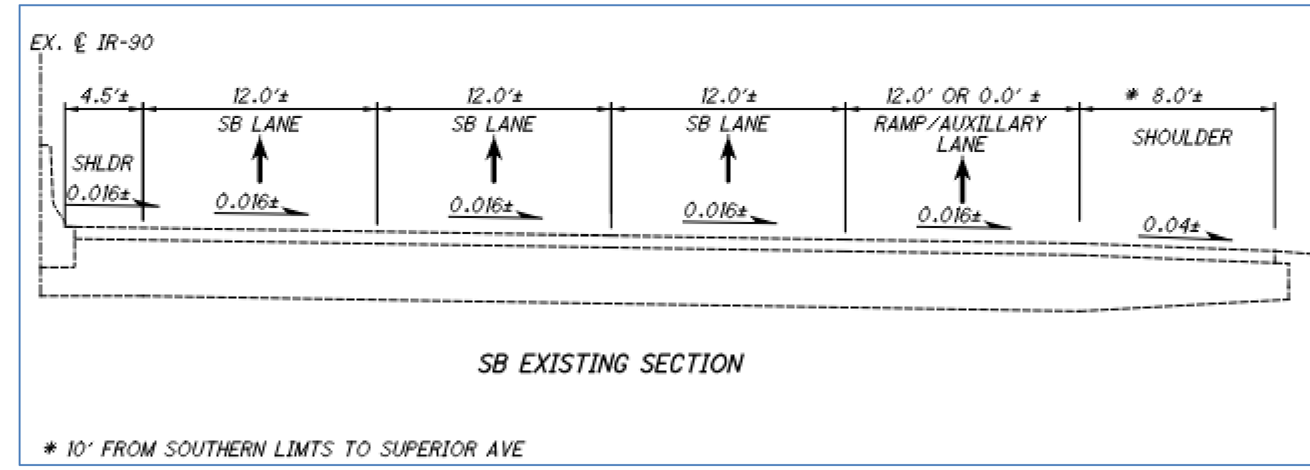

Figure 6 – Existing Typical Section of I-90 WB from SR 2 to East 22nd Street (Normal Crown)

ODOT is currently developing construction plans for a significant reconstruction of the I-90 and I-77 interchange in the Central Interchange section of the corridor. Detailed design plans are currently being completed with construction expected to start in 2024 based on available funding. This construction will implement additional capacity and lanes along I-90 between East 22nd Street and I-77, new ramp alignments between I-90 and I-77, and capacity improvements to I-77 from I-90 to I-490. At the end of this construction, I-90 WB will be three lanes under the existing Carnegie Avenue bridge and opens to four lanes between Carnegie Avenue and East 22nd Street. At the diverge to I-77 SB, the four lanes along I-90 WB will split to two lanes exiting to I-77 (as a drop/decision) and three lanes continuing along I-90 WB.

The purpose of the I-90 WB SmartLane study is to identify feasible alternatives to address the congestion and safety issues along I-90 WB from East 55th Street to East 22nd Street, while also being compatible with adjacent project improvements.

Logical Termini and Independent Utility

The logical termini for the feasibility study on i-90 WB is East 22nd Street to the south and East 55th Street to the north. The selection of these termini allows for the inclusion of the Prospect Avenue interchange to the south and the SR 2 interchange on the north side. This section of I-90 WB experiences significant congestion during the PM peak hour. The I-71 and I-90 interchange improvement design work to the south is assumed to be implemented as the southern terminus of this study but this study could also be implemented prior to this interchange improvement if desired.

The proposed project does not rely on any other project to meet the established purpose. Additionally, it is independent of any other transportation improvement in the area and does not preclude any future project. Therefore, independent utility is established for the proposed project.

CHAPTER 3: ALTERNATIVES CONSIDERED

I-90 is a high-speed urban interstate facility (50-mph posted speed limit) with a concrete barrier separating the two directions of travel through this section. I-90 WB is primarily a 3-lane facility with auxiliary lanes between interchanges to provide a fourth lane between SR 2 and East 22nd Street. Through the SR 2 interchange at the north end, I-90 WB is reduced to two through lanes. In this section, I-90 is part of the National Highway System (NHS). I-90 travels under several bridges between East 55th Street and East 22nd Street, including SR 2 (SFN #1808222), South Marginal Road (SFN #1808192), CSX Railroad (SFN #1809415), Lakeside Avenue (SFN #1808168), NS Railroad (SFN #1809350), Hamilton Avenue (SFN #1808133), St. Clair Avenue (SFN #1808109), Superior Avenue (US 6, SFN #1808079), Payne Avenue (SFN #1808044), Chester Avenue (US 322, SFN #1807986), Euclid Avenue (US 20, SFN #1807951), Prospect Avenue (SFN #1807927), Carnegie Avenue (SFN #1807897), Cedar Avenue (SFN #1807862), and East 22nd Avenue (SFN #1807838).

Two conceptual "Build" alternatives were studied to reduce the congestion along I-90 WB. These two alternatives were not compared to the *No-Build* alternative because it is known that the *No-Build* alternative doesn't alleviate the congestion and safety concerns in the corridor. The criteria used to compare the alternatives is discussed in the next section of this report. The ODOT Location and Design (L&D) Manual, Volume 1 was used as the source of roadway and geometric design criteria for the conceptual alignments. The following design criteria has been set and was followed for the Build alternatives studied:

- I-90
  - Functional Classification = Urban Interstate (NHS/National Truck Network Route)
  - Design Speed = 55 mph
  - Posted Speed = 50 mph
  - Lane Width = 12'-0"
  - Shoulder Width = 10'-0" left, 10'-0" right
- Single Lane Ramps
  - Functional Classification = Ramp
  - Design Speed = Varies
  - Posted Speed = N/A
  - Lane Width = 16'-0"
  - Shoulder Width = 3'-0" left (4'-0" adjacent to barrier) and 6'-0" right
- Two Lane Ramps
  - Functional Classification = Ramp
  - Design Speed = Varies
  - Posted Speed = N/A
  - Lane Width = 12'-0"
  - Shoulder Width = 4'-0" left and 10'-0" right

Both Build alternatives were compared based on the following criteria, which is explained in more detail in Chapter 4 of this report.

- Safety Performance
- Traffic Operations
- Adherence to Geometric Standards
- Estimated Construction Costs

Chapter 5 describes how the alternatives compare to one another with respect to these criteria.

Construction cost estimates were developed for each of the alternatives, and can be found in ***Appendix H***. Both Build alternatives are depicted in ***Appendix A*** and discussed in further detail in the next section of the report.

This study evaluated whether implementing a SmartLane strategy would be feasible through this corridor. SmartLane is the ODOT-named initiative of using the shoulder as a part-time lane to address congestion concerns. The shoulder is used as a lane during peak periods of congestion when needed, then would be returned to a shoulder during non-peak periods of congestion. Changeable message boards are used to communicate to drivers when it is appropriate to use the part-time shoulder lane and typically numerous cameras are placed along the corridor to allow for operators to monitor the SmartLane corridor remotely for any obstructions that may be in the shoulder lane. An example of this strategy was recently implemented in Ohio along I-670 EB between downtown Columbus and I-270, the outerbelt around the city. ***Figure 7*** and ***Figure 8*** shows the SmartLane in use along the I-670 corridor in Columbus, Ohio.

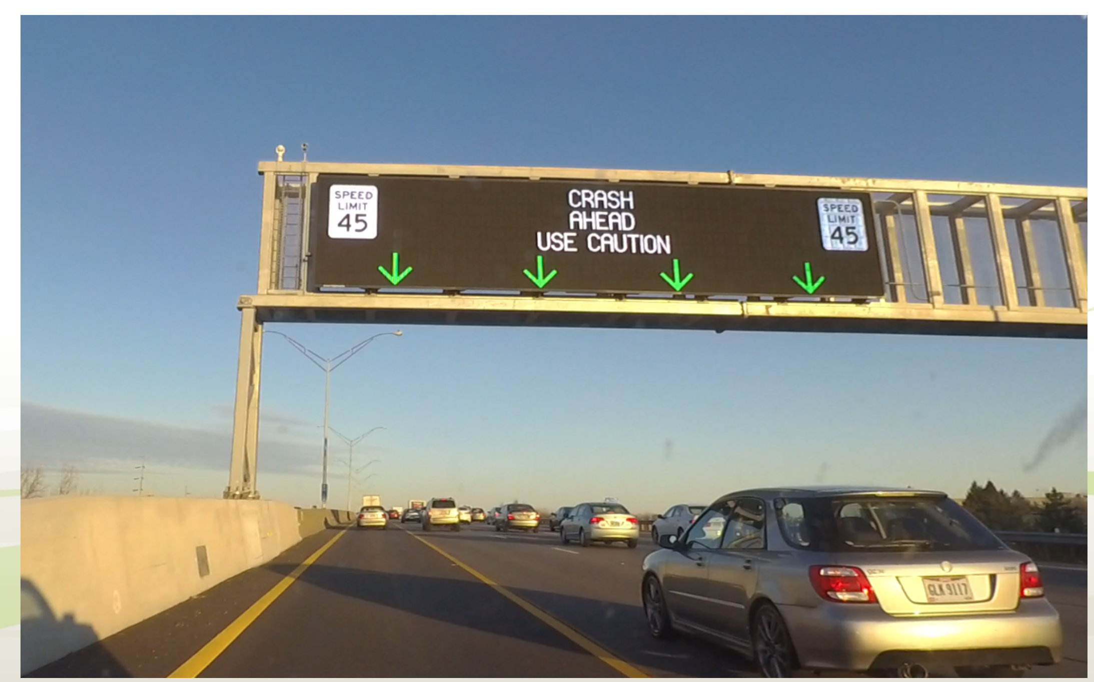

Figure 7 – SmartLane along I-670 EB in Columbus, Ohio

Figure 8 – SmartLane along I-670 EB in Columbus, Ohio

The SmartLane can be implemented in either the left (inside) or right (outside) shoulder. There are benefits and challenges of each. Using the left shoulder eliminates the interaction of the SmartLane with the interchange ramps that are entering and exiting the freeway on the outside. However, if the left shoulder isn't wide enough to adequately incorporate a travel lane and the necessary lateral offset to the barrier or other obstructions, the cost to widen the pavement and shift all the travel lanes away from the median barrier could be extensive. Using the right shoulder allows for targeted widening to accommodate the necessary width of the travel lane without impacting the other freeway lanes but requires interaction with the interchange ramps, which can lead to confusion by drivers when the SmartLane is open or closed. For this study, both an inside and outside SmartLane was initially evaluated. The outside SmartLane was dismissed early in the process and is documented later in this chapter. The inside SmartLane was further analyzed, leading to two alternatives. Both alternatives are similar in the treatment of the SmartLane except for the starting point.

The roadway typical section of I-90 WB for both alternatives in this section where the SmartLane is being proposed utilizes 11-foot wide travel lanes for all but one lane for the general-purpose lanes (one of the lanes is proposed to be 12-feet wide to accommodate national network requirements for freight movement) and an 11 foot wide SmartLane alongside a 3 foot wide shoulder adjacent to the median barrier. When the SmartLane is not open to traffic, this left-hand shoulder would be 14 feet wide. The outside shoulder varies in width from as narrow as 1.79 feet (under the proposed Carnegie Avenue bridge being constructed with the CCG3 project) up to 10 feet outside of the bridge areas where additional pavement can be placed to widen the roadway section. See ***Figure 9*** for the proposed 4-lane typical section and ***Table 1*** for the shoulder width table refenced in the typical section.

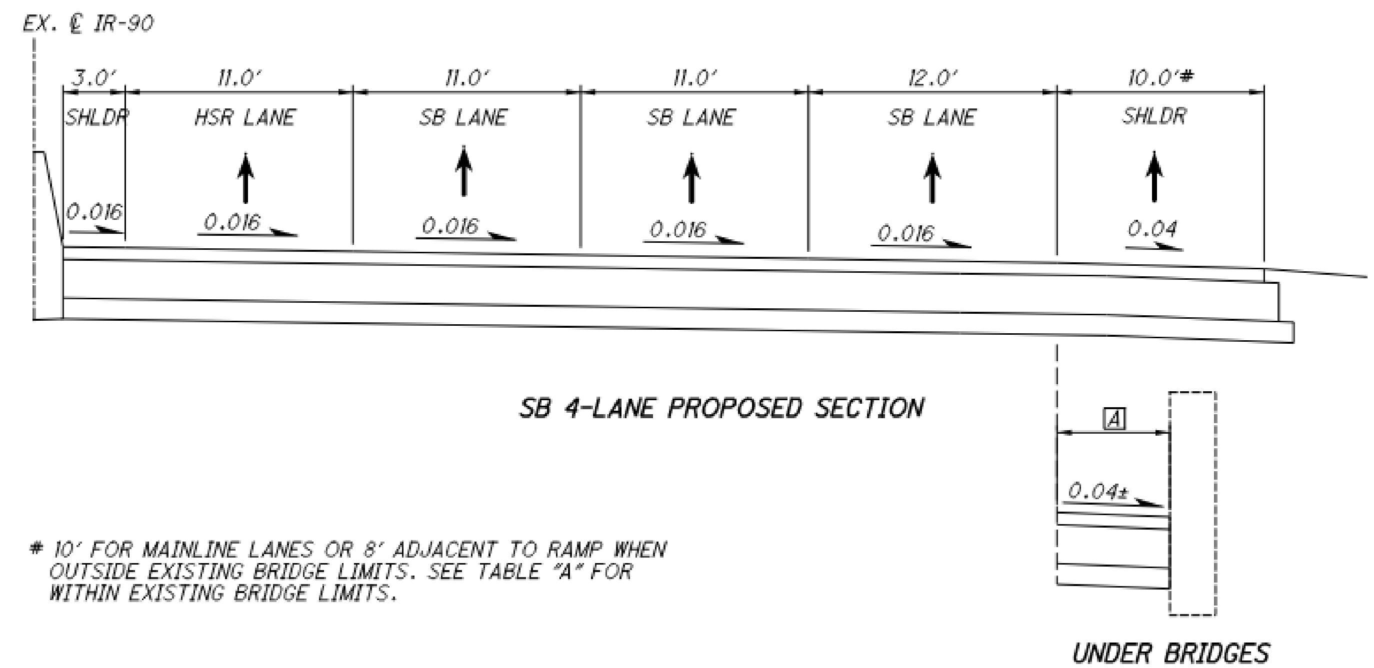

Figure 9 – Proposed 4-lane typical section when SmartLane is open to traffic

Table 1 – Proposed shoulder width table for use with typical section

A SHOULDER WIDTH TABLE

Bridge	Existing No. Lanes		Existing Lateral Clearance		Prop. Outside Shoulder
	Mainline	Ramp/Auxiliary	Plans	Survey	
SR-2	2	0	39.25	N/A	2.25
S Marginal Rd	2	2	63.25	N/A	4.25
Railroad	2	2	63.04	N/A	4.04
Lakeside Ave E	3	1	63.25	N/A	4.25
Railroad	3	1	62.5	N/A	3.50
Hamilton Ave	3	1	63.25	N/A	4.25
St Clair Ave NE	3	1	63.25	N/A	4.25
Superior Ave/US-6	3	0	53.25	56.20	8.20
Payne Ave	3	1	63.25	62.97	3.97
Chester Ave/US-322	3	1	63.25	64.00	5.00
Euclid Ave/US-20	3	1	63.25	61.83	2.83
Prospect Ave E	3	1	63.25	N/A	4.25
Carnegie Ave	4	0	60.79	N/A	1.79

Note: All bridges are over the mainline

Note: Carnegie Ave latereal clearance is based on current CCG3 bridge plans

Due to the narrow lateral clearance available under the existing SR 2 bridge over I-90, one option was developed that began the SmartLane west of SR 2 and the other option began the SmartLane east of SR 2. See ***Figure 10*** for a Google Street View image of I-90 WB traveling under the SR 2 bridge.

Figure 10 – Google Street View of I-90 WB traveling under the existing SR 2 Bridge

Alternative 1: West of SR 2 Start

Alternative 1 proposes beginning the SmartLane west of the SR 2 interchange due to total narrow lateral clearance width of 39.25 feet available under the existing SR 2 bridge over I-90 for the I-90 WB lanes. For this alternative, the two existing I-90 WB lanes comes around the horizontal curve and travels under the existing SR 2 bridge in their same location. The two lanes from SR 2 EB add to I-90 WB south of the SR 2 bridge to form four lanes on I-90 WB that travel under the existing South Marginal Road bridge and the existing CSX railroad bridge. South of the railroad bridge, the general-purpose travel lanes along I-90 WB shift to the west (outside) away from the median barrier. Once shifted enough, the SmartLane begins on the left (inside) immediately north of the entrance ramp from Lakeside Avenue, making five lanes available when the SmartLane is open. These five lanes continue west to drop a lane at the Superior Avenue/East 26th Street exit ramp, allowing four lanes to continue west past this diverge and under the Superior Avenue bridge. Between the entrance ramp from Superior Avenue and the exit to Chester Avenue, an auxiliary lane is formed to make five lanes along I-90 WB under the Payne Avenue bridge. Between the exit to Chester Avenue and the entrance from Chester Avenue, four lanes are available when the SmartLane is open. Another auxiliary lane is developed between the entrance ramp from Chester Avenue and the exit ramp to Prospect Avenue, making five lanes in this section. Between the exit to Prospect Avenue and the entrance from Prospect Avenue, four lanes are available when the SmartLane is open. Finally, the Prospect Avenue entrance ramp merges into the mainline to create four lanes along I-90 WB at the southern end of the project study area. These four lanes match into the proposed four-lane typical section of the Construction Contract Group 3 (CCG3) project which is implementing the capacity improvements at the I-90 and I-77 interchange. The SmartLane forms the inside general-purpose lane in the CCG3 project. The termination is expected to be like how the SmartLane is terminated along I-670 EB in Columbus. See ***Figure 11*** for how this terminates on I-670.

Figure 11 – Termination of I-670 EB SmartLane

Alternative 2: East of SR 2 Start

Alternative 2 proposes beginning the SmartLane east of the SR 2 interchange. For this alternative, the four existing I-90 WB lanes are present between East 55th Street and SR 2. At this point, the general-purpose travel lanes along I-90 WB shift to the west (outside) away from the median barrier. Once shifted enough, the SmartLane begins on the left (inside) approximately 4,000 feet east of the SR 2 interchange, making five lanes available when the SmartLane is open. These five lanes split as two lanes exit to SR 2 WB and three lanes continue along I-90 WB around the horizontal curve and travel under the SR 2 bridge. South of SR 2, the two lanes from the SR 2 EB entrance ramp combine with the three lanes along I-90 WB to make five lanes traveling under the South Marginal Road and CSX bridges. South of the CSX bridge, this alternative replicates *Alternative 1*, including number of lanes, location of auxiliary lanes, and termination at the south end of the study area into CCG3.

Alternative 3: No-Build

This alternative does not make any changes to the existing corridor and maintains the existing number of lanes along I-90 WB.

Alternatives Evaluated and Dismissed

During this study, an additional alternative was evaluated that added capacity along I-90 WB.

<u>Outside SmartLane</u>

This alternative proposed placing the SmartLane along the outside of I-90 WB. This was identified as an option due to the concern over the narrow existing inside shoulder width. For this alternative, the SmartLane began after the diverge to SR 2 WB as a standard 100-foot long taper to introduce the additional lane on the outside to create three lanes traveling under the SR 2 bridge. The SmartLane was placed between the second I-90 general-purpose lane when counted from the median barrier and the two-lane entrance ramp from SR 2 EB, creating five lanes south of the SR 2 interchange. This created a challenge as only one of the two lanes that entered from SR 2 EB are exiting to Superior Avenue, leaving a single lane to the right (outside) of the SmartLane south of the Superior Avenue interchange. This would likely create considerable driver confusion when the SmartLane was closed since there would be significant pavement width between the two lanes with no specific purpose during off-peak periods. To alleviate this, the SR 2 EB entrance ramp would need to be reduced to a single lane, which would likely create considerable signing and weave issues along SR 2 EB approaching the I-90 interchange. In the existing condition, with the SR 2 EB entrance ramp being two lanes, the traffic from SR 2 EB approaching the I-90 interchange doesn't have to shift lanes to exit. If the entrance ramp was reduced to a single lane, then SR 2 EB traffic would need to move to the right to exit to I-90 WB, while at the same time vehicles entering from East 9th Street and the municipal parking lot entrance ramps would need to move left to continue to I-90 EB, creating a weaving conflict in a short length of freeway. Further along I-90 WB, auxiliary lanes that are present between the Superior Avenue and Chester Avenue interchanges and the Chester Avenue and Prospect Avenue interchanges would be located outside of the SmartLane, again creating a situation where there is additional pavement width between the lanes with no specific purpose when the SmartLane is closed. The placement of the SmartLane and the expected confusion due to the interaction with the auxiliary lanes and two-lane entrance ramp is why this alternative was dismissed from further consideration.

CHAPTER 4: KEY ISSUES

Additional assessment was completed on the conceptual alternatives being proposed for this corridor improvement. The objective of this additional analysis was to determine the feasibility of each alternative as well as identifying those elements critical to the implementation of each alternative that need to be addressed with further analysis. This effort helped identify the costs and benefits of each alternative. A summary of the key analyses and assessments is provided in the next section of this report.

Safety Performance

Using the methodologies in the *Highway Safety Manual* (HSM) through ODOT's Economic Crash Analysis Tool (ECAT), the safety performance for three scenarios were evaluated - *No Build*, *Build with SmartLane Closed*, and *Build with SmartLane Open*. For the purposes of this analysis, the limits of this analysis included mainline I-90 WB from approximately 0.22 miles west of the SR 2 exit to the I-77 SB exit.

The *Build with SmartLane Closed* condition included the shoulder and lane width changes caused by the construction of the wider inside shoulder for use as the SmartLane. An additional travel lane and reduced inside shoulder and offset to the median barrier were analyzed under the *Build with SmartLane Open* condition. The traffic volumes used under the *No Build* condition were also used for both Build conditions. Making no other improvements to the freeway, the analysis showed an increase in predicted fatal and injury crash frequency as a result of vehicles traveling closer to the barrier when the SmartLane was open. However, the frequencies for property damage only crashes were reduced with the improvements of adding an additional lane of capacity. When the SmartLane was closed and without any additional improvements, there was a slight increase in fatal and serious injury crashes and a reduction in crashes of minor and possibly injury crashes as well as property damage only crashes over the *No Build* condition. Therefore, other mitigation strategies were considered to reduce the number of crashes along these freeway segments, specifically when the SmartLane was operational.

One benefit of installing the SmartLane is the implementation of variable speed limits (VSL) and dynamic lane information signs that can be used to alert motorists, even when the SmartLane is not open, that a hazard exists in a downstream lane – either a general-purpose lane or in the SmartLane. Based on recent research, the crash modification factor (CMF) for this improvement is 0.71 for all crash types and severities which results in a reduction in 29 percent of the crashes. The benefits of VSL and dynamic lane messaging will also be recognized when the SmartLane is closed. Therefore, this CMF was applied to the *Build with SmartLane Open* and *Build with SmartLane Closed* scenarios.

The HSM predicts crashes as a function of daily volumes and assumes a consistent cross-section throughout the day. Because the cross-section changes with the operation of the SmartLane, a weighted average based on the hours of operation and the percent of AADT during those hours was used to determine the true safety impacts of the SmartLane. The SmartLane operation will be driven by congestion and average speeds of the freeway. Based on the monthly volume report at ATR location 100218, the SmartLane would most likely be warranted for about three hours per day between the hours of 3 PM and 6 PM. This time period contains approximately between 21 and 28 percent of the daily traffic volumes along I-90 WB. Therefore, 25 percent of the predicted number of crashes for the *Build with SmartLane Open* condition was added to 75 percent of the predicted number of crashes for the *Build with SmartLane Closed* condition to obtain the final predicted number of crashes for the Build condition.

Traffic Operations

The Traffic Analysis study area includes I-90 WB beginning west of the East 55th Street interchange and ending west of the I-77 off-ramp. Because this improvement is considered an interim condition intended to provide congestion relief until the ultimate improvements for I-90 are funded and constructed, the capacity analysis for the study area was conducted using the existing traffic volumes.

Traffic Volume Projections – Existing traffic volumes for the corridor were developed by Michael Baker as part of the 2018 "Auxiliary Lane-Permanent 4-Lane Memorandum". A combination of the certified traffic, 2015 counts conducted by Baker and 2016 counts conducted by ODOT were used to develop the existing condition volumes for the corridor. The volumes from this study were then increased by 5% to represent a 2021 existing condition. Exhibits showing the 2021 existing traffic volumes for the corridor are contained in ***Appendix D***. The SmartLane is not intended to solve the capacity issues in the corridor for the design year. This will be accomplished through the construction of the I-90 Trench and Innerbelt Curve projects from the approved interchange justification study. Instead, the goal of the SmartLane is to improve the existing condition, which will allow for improved operations in the corridor until the ultimate condition can be built. For this reason, the 2021 existing traffic was used for the analysis.

Capacity Analysis - Capacity Analysis was conducted for the 2021 No-Build and Build alternatives. Analysis was conducted in the Freeway Facilities module of the *Highway Capacity Software (HCS), version 7.9.6*. The use of the Freeway Facilities module in HCS allows the freeway segments, merges, diverges and weaves to be evaluated as a system. It computes performance measures for each of the individual segments within a study corridor, includes the inter-segment impacts of traffic congestion on all affected segments, and provides overall performance measures for the entire study corridor. As stated in the *Highway Capacity Manual*, the methodology is consistent with individual segment methodologies if all demand volume-to-capacity (*D/C*) ratios are less than 1.00 and it properly accounts for the interaction of segments when any *D/C* ratio is greater than 1.00. Analysis of individual segments may fail to capture potential bottleneck impacts at one segment on adjacent upstream and downstream segments. A bottleneck on one segment that is over capacity will reduce the throughout volume on downstream links because the full demand will be unable to travel through the bottleneck. Likewise, links upstream of the bottleneck will have additional queuing and delay caused by the bottleneck. This interaction between segments is captured in the Freeway Facilities analysis. ***Table 2*** shows the results of the capacity analysis for the No-Build and SmartLane alternatives.

Table 2 – Capacity results for I-90 WB

Segment	Analysis Type	Location (Westbound I-90)	2021 AM Peak												2021 PM Peak											
			No-Build				Alternative 1				Alternative 2				No-Build				Alternative 1				Alternative 2			
			LOS	v/c	d/c		LOS	v/c	d/c		LOS	v/c	d/c		LOS	v/c	d/c		LOS	v/c	d/c		LOS	v/c	d/c	
					F*	R*			F*	R*			F*	R*			F*	R*			F*	R*			F*	R*
Seg-1	Basic	West of E. 55th On-Ramp	F	0.77	0.92	-	F	0.77	0.92	-	E	0.92	0.92	-	C	067	0.69	-	C	0.67	0.69	-	C	0.69	0.69	-
Seg-2	Basic	East of WB SR 2 Off-Ramp	F	0.77	0.96	-	F	0.77	0.96	-	D	0.77	0.77	-	F	0.64	0.72	-	F	0.64	0.72	-	C	0.58	0.58	-
Seg-3	Diverge	WB SR 2 Off-Ramp	F	0.75	0.96	0.74	F	0.75	0.96	0.74	E	0.77	0.77	0.74	F	0.61	0.72	0.46	F	0.61	0.72	0.4	D	0.58	0.58	0.46
Seg-4	Basic	East of EB SR 2 On-Ramp	F	0.77	1.22	-	F	0.77	1.22	-	E	0.82	0.82	-	F	0.77	1.02	-	F	0.77	1.02	-	E	0.68	0.68	-
Seg-5	Merge	SR 2 On-Ramp	F	0.93	0.93	0.21	F	0.93	0.93	0.21	E	0.91	0.91	0.21	F	0.93	0.93	0.21	F	0.93	0.93	0.2	D	0.78	0.78	0.21
Seg-6	Merge	26th Street On-Ramp	C	0.47	0.47	0.02	C	0.47	0.47	0.02	C	0.55	0.55	0.02	C	0.51	0.51	0.23	C	0.51	0.51	0.2	C	0.50	0.50	0.23
Seg-7	Diverge	Superior Avenue Off-Ramp	C	0.47	0.47	0.41	C	0.47	0.47	0.41	C	0.55	0.55	0.41	C	0.51	0.51	0.23	B	0.41	0.41	0.2	C	0.50	0.50	0.23
Seg-8	Basic	East of Superior Avenue On-Ramp	C	0.51	0.80	-	C	0.51	0.80	-	C	0.60	0.60	-	C	0.61	0.77	-	C	0.46	0.58	-	C	0.58	0.58	-
Seg-9	Weaving	Between Superior On and Chester Off	C	0.48	0.72	#	C	0.48	0.79	#	C	0.58	0.58	#	C	0.59	0.72	#	C	0.47	0.58	#	C	0.58	0.58	#
Seg-10	Basic	East of Chester Avenue On-Ramp	C	0.49	0.79	-	C	0.49	0.79	-	C	0.59	0.59	-	D	0.69	0.85	-	C	0.52	0.64	-	D	0.64	0.64	-
Seg-11	Weaving	Between Chester On and Prospect Off	C	0.52	0.77	#	C	0.52	0.77	#	D	0.63	0.63	#	D	0.68	0.81	#	C	0.54	0.65	#	D	065	0.65	#
Seg-12	Basic	East of Prospect Avenue On-Ramp	C	0.46	0.75	-	C	0.46	0.75	-	C	0.56	0.56	-	D	0.80	0.96	-	C	0.60	0.72	-	D	0.72	0.72	-
Seg-13	Merge	Prospect Avenue On-Ramp	B	0.54	0.54	0.16	B	0.54	0.54	0.16	C	0.64	0.64	0.16	F	0.91	0.91	0.17	C	0.68	0.68	0.1	C	0.81	0.81	0.17
Seg-14	Overlap	East of I-77 Off-Ramp	D	0.51	0.80	-	D	0.51	0.80	-	C	0.60	0.60	-	F	0.85	1.00	-	D	0.63	0.75	-	D	0.75	0.75	-
Seg-15	Diverge	I-77 Off-Ramp	B	0.38	0.38	0.45	B	0.38	0.38	0.45	B	0.48	0.48	0.45	B	0.63	0.63	0.40	B	0.51	0.51	0.4	B	0.60	0.60	0.40
Seg-16	Basic	West of I-77 Off-Ramp	A	0.22	0.52	-	A	0.22	0.52	-	C	0.52	0.52	-	C	0.59	0.75	-	C	0.59	0.75	-	D	0.75	0.75	-
Facility Length, mi			3.95				3.95				3.95				3.95				3.95				3.95			
Space Mean Speed, mi/h			28.8				28.8				51.4				38.3				38.5				52.5			
Density, pc/mi/ln			43.6				43.6				29.3				37.8				32.4				27.2			
Density, veh/mi/ln			41.2				41.2				27.3				35.7				34.3				25.4			
Travel Time, min			8.20				8.20				4.60				6.20				6.20				4.50			
LOS			F				F				D				F				F				D			

The LOS results reported are based on the vehicles able to pass through a segment and is dependent on upstream and downstream bottlenecks in the corridor. D/C ratios are also included and represent how the segment would operate if there were no upstream bottlenecks and the full traffic demand passed through the segment. Finally, the volume-to-capacity (V/C) ratios for each segment has been reported. This is based on the volume that can actually pass through a segment. If there are no bottlenecks in the corridor the V/C and D/C ratios for each segment would be the same. A difference between the V/C and D/C ratios is an indication that there is congestion on the corridor and upstream bottlenecks are preventing the full traffic demand from reaching this segment. Capacity results are discussed below, and *HCS* capacity analysis outputs are contained in ***Appendix E.***

No-Build Capacity Results - In the *No-Build* condition there are two issues in the corridor causing poor levels of service. The most significant is the two-lane mainline segment through the SR 2 interchange (segment 4). This segment is over capacity in both the AM and PM peak hours, which meters the traffic able to reach the downstream segments of the corridor. In addition, the congestion caused by this two-lane segment will ripple upstream and cause LOS F conditions to the East 55th Street interchange. The second congestion hotspot is the mainline segment between the Prospect Avenue on-ramp and the I-77 diverge (segment 14). Even with the reduced traffic volume caused by the upstream bottleneck at SR 2, this segment is expected to operate at LOS F in the PM peak hour. Depending on how much traffic gets through the SR 2 interchange on any given day, LOS F conditions will extend upstream to at least Prospect Avenue, and maybe farther. In the AM peak hour, the average speed through the corridor is 28.8 mph and the travel time from E.55th Street to I-77 is 8.20 minutes. In the PM peak, the average speed is 38.3 and the travel time is 6.20 minutes.

Alternative 1 Capacity Results – In this alternative, a SmartLane is added west of the SR 2 interchange, near the 26th Street on-ramp (segment 6) and carried to the I-77 diverge. Starting the additional lane west of SR 2 does not address the capacity issue through the SR 2 interchange. As a result, the two-lane segment through the interchange operates at LOS F and is over capacity. Like the No-Build condition, traffic will be metered, and the LOS F conditions will extend upstream to the East 55th Street interchange. Downstream of SR 2, the SmartLane will improve the operations between Prospect Avenue and I-77. However, this results in very little benefit to the overall corridor operations. For the analysis the SmartLane will provide no benefit to the AM peak so it was assumed that the SmartLane would be in operation during PM peak hours only. Overall, the corridor is operating similar to the *No-Build* condition. During the AM peak hour, the average speed is 28.8 mph and the travel time is 8.20 minutes. In the PM peak the average speed increased from 38.3 mph in the *No-Build* to 38.5 mph and the travel time remained at 6.20 minutes.

Alternative 2 Capacity Results – In this alternative, a SmartLane is added between the East 55th Street on-ramp and the WB SR 2 off-ramp (segment 2) and carried to the I-77 diverge. This additional lane addresses the two capacity issues from the *No-Build* condition. First, the additional lane through the SR 2 interchange allows the full demand traffic volume to pass through the interchange. While it is still expected to operate at LOS E, it is a significant improvement over the No-Build condition. Between Prospect Avenue and I-77 (segment 14) the additional lane from the SmartLane has improved the operation from LOS F to LOS D. For the analysis it was assumed that the SmartLane would be in operation during both the AM and PM peak hours. Overall, the entire corridor is operating at LOS D and there are no bottlenecks that are metering traffic flow. During the AM peak hour, the average speed has increased from 28.8 mph in the No-Build to 51.4 mph and the travel time has reduced from 8.20 minutes in the No-Build to 4.60 minutes. Similar results were obtained in the PM peak where the average speed increased from 38.3 mph to 52.5 mph and the travel time reduced from 6.20 minutes to 4.50 minutes.

Adherence to Geometric Standards

Each Build alternative was evaluated based on their ability to meet geometric standards established for freeways in ODOT's Location and Design (L&D) Manual, Volume 1.

Lane Width – The roadway typical section of I-90 WB for both alternatives in this section where the SmartLane is being proposed utilizes 11-foot wide travel lanes for all but one lane for the general-purpose lanes (one of the lanes is proposed to be 12-feet wide to accommodate national network requirements for freight movement) and an 11 foot wide SmartLane. Autoturn truck turning software was used to identify truck swept paths through the SR 2 Curve and the Carnegie Curve to determine if the proposed typical section of 11-foot wide lanes (and a single 12-foot wide lane) can accommodate a WB-62 design vehicle. In the SR 2 Curve, it was determined that using 11-foot wide lanes, the trucks make it through the curve while encroaching about 3 inches into the adjacent lane. Further Highway Safety Manual (HSM) analysis may be desired to determine if providing slightly greater lane width and reducing the proposed shoulder width to eliminate this encroachment in this section is appropriate. In the Carnegie Curve, the trucks can make it through the curve wholly within their lane. See ***Appendix F*** for exhibits showing the truck turns through these two curves. A design exception would be required for lane width when at least 12 feet, meeting standards per L&D Volume 1, Figure 301-4, isn't provided.

Shoulder Width/Lateral Clearance – In both Build alternatives, the proposed 11-foot wide SmartLane is alongside a 3-foot-wide shoulder adjacent to the median barrier. When the SmartLane is not open to traffic, this left-hand shoulder would be 14 feet wide. The outside shoulder varies in width from as narrow as 1.79 feet (under the proposed Carnegie Avenue bridge being constructed with the CCG3 project) up to 10 feet outside of the bridge areas where additional pavement can be placed to widen the roadway section. Under the existing bridges, the proposed outside shoulder was calculated using the existing lateral clearance either from the existing bridge plans or from detailed survey as noted in ***Table 3***, which shows the proposed outside shoulder calculated under each overhead bridge through the corridor.

Table 3 – Proposed outside shoulder under the overhead bridges along I-90 WB

I-90 WB Hard Shoulder Running (HSR) Study Lateral Clearance At Existing Bridges					
Bridge	**Existing No. Lanes**		**Existing Lateral Clearance**		**Prop. Outside Shoulder**
	Mainline	**Ramp/Auxiliary**	**Plans**	**Survey**	
SR-2	2	0	39.25	N/A	2.25
S Marginal Rd	2	2	63.25	N/A	4.25
Railroad	2	2	63.04	N/A	4.04
Lakeside Ave E	3	1	63.25	N/A	4.25
Railroad	3	1	62.5	N/A	3.50
Hamilton Ave	3	1	63.25	N/A	4.25
St Clair Ave NE	3	1	63.25	N/A	4.25
Superior Ave/US-6	3	0	53.25	56.20	8.20
Payne Ave	3	1	63.25	62.97	3.97
Chester Ave/US-322	3	1	63.25	64.00	5.00
Euclid Ave/US-20	3	1	63.25	61.83	2.83
Prospect Ave E	3	1	63.25	N/A	4.25
Carnegie Ave	4	0	60.79	N/A	1.79

To get this value, the number of existing lanes, assuming one is 12-feet wide and the rest are 11-feet wide, plus the 11-feet wide SmartLane, plus the 3-foot wide inside shoulder were subtracted from the existing lateral clearance width. The remaining width was allocated as proposed outside shoulder width. A design exception would be required for shoulder width when at least 10 feet, meeting standards per L&D Volume 1, Figure 301-4, isn't provided. In areas where the lateral clearance is too narrow to provide a minimum 10-foot wide outside shoulder, mitigation strategies should be investigated, such as advisory signs and the use of high-friction pavement surface course.

<u>*Horizontal Stopping Sight Distance*</u> – The horizontal stopping sight distance (HSSD) for the mainline curves was evaluated for both alternatives. There are three horizontal curves in the project study area along I-90 WB: a) through the SR 2 interchange – curve to the left in the direction of travel (identified as "SR 2 Curve" in this report); b) north of Superior Avenue – curve to the right in the direction of travel (identified as "Superior Curve" in this report); and c) underneath Carnegie Avenue – curve to the right in the direction of travel (identified as "Carnegie Curve" in this report). ***Table 4*** summarizes the results of the HSSD analysis for the three horizontal mainline curves as the general-purpose lanes are shifted to the outside and the inside shoulder width is reduced with the addition of the left-side SmartLane. Because *Alternative 1* begins west of the SR 2 interchange, the SR 2 Curve proposed HSSD values don't apply to *Alternative 1*.

Table 4 – I-90 WB Mainline Curve HSSD Summary

Mainline Curve Name	Mainline Curve Radius (feet)	Lane CL (ft)		Barrier Offset From CL (ft)		Horizontal SSD	
		Existing	Proposed	Existing	Proposed	Existing	Proposed
SR 2 Curve	478-feet (11.98 degrees)	472	460	10	7	195 ft (29 MPH)	160 ft (25 MPH)
			471		18		261 ft (32 MPH)
Superior Curve	3724-feet (1.75 degrees)	3213	3209	15	10	621 ft (63 MPH)	506 ft (55 MPH)
Carnegie Curve	1648-feet (3.48 degrees)	1615	1603	33	21.5	654 ft (65 MPH)	525 ft (57 MPH)

Through the SR 2 Curve, the HSSD is reduced in the SmartLane from 195 feet (29 mph – existing) to 160 feet (25 mph – proposed). With the implementation of the SmartLane, there will be numerous CCTV cameras installed to allow for the Traffic Management Center (TMC) operator to maintain watch over the entire corridor, including around this horizontal curve. The TMC operator can warn drivers on the DMS boards if there is an obstruction in the SmartLane and can close the lane remotely from the TMC. This HSSD reduction is for the SmartLane. When the SmartLane is closed, this reduction of HSSD isn't present. Through the SR 2 Curve, the HSSD in the left-hand general-purpose lane, the lane immediately adjacent to the SmartLane, is increased from 195 feet (29-mph – existing) to 261 feet (32 mph – proposed). This change through the SR 2 Curve is only present in *Alternative 2*. The Superior Curve and the Carnegie Curve both curve to the right, so the inside SmartLane HSSD isn't impacted. The outside lane is impacted in both *Alternative 1* and *Alternative 2* because it is shifted away from the median barrier and closer to the bridge and wall obstructions that are present on the outside of the pavement. For the Superior Curve, the HSSD for the outside general-purpose and auxiliary lane is reduced from 621 feet (63 mph – existing) to 506 feet (55 mph – proposed). The HSSD provided through the Carnegie Curve is reduced from 654 feet (65 mph – existing) to 506 feet (55 mph - proposed). Additional camera coverage may be warranted in the areas where HSSD is reduced and coordination should occur with the TMC to ensure that expectations are realistic that their operators can adequately manage the additional coverage and oversight. See ***Appendix F*** for the information shown in ***Table 4***. A design exception would be required for HSSD when at least 495 feet, meeting 55-mph standards per L&D Volume 1, Figure 201-1, isn't provided.

<u>*Vertical Clearance*</u> – The portion of I-90 WB from East 55th Street to the SR 2 Curve is normal crowned with the pavement all sloping away from the median barrier using a 1.6% cross slope, making the pavement edge adjacent to the median barrier higher than the outside edge of pavement. Through the SR 2 Curve, the pavement is superelevated at approximately 4.4% cross slope toward the median barrier, making the outside edge of traveled way higher than the pavement adjacent to the median barrier, making the outside edge of traveled way the controlling point for vertical clearance under the SR 2 bridge. The outside shoulder slopes away from the traveled lanes using a 1% cross slope. Along I-90 WB west of the SR 2 bridge, the pavement is all sloping away from the median barrier either using the normal crown (1.6%) cross slope or superelevated (3-6%) so that the outside edge of traveled way is lower than the pavement edge adjacent to the median barrier, making the inside edge of pavement the controlling point for vertical clearance and a non-issue under the bridges.

Per Figure 302-2 of the L&D Volume 1, the minimum allowed vertical clearance is 14.5 feet if there is an alternative interstate route that meets the minimum 16-foot vertical clearance requirement. For this report, it is assumed that I-271 to I-480 would be that alternative interstate route but this needs to be confirmed. The existing minimum vertical clearance at each of the overpasses are as follows from the Bridge Inventory Appraisal Reports (*italicized* with * denotes from actual survey of the bridge clearance; **bolded** value represents the minimum vertical clearance along I-90 WB through the study limits):

- SR 2: *15.06 feet **
- South Marginal Road: 15.1 feet
- CSX Railroad: 15.0 feet
- Lakeside Avenue: 15.1 feet
- **NS Railroad: 14.7 feet**
- Hamilton Avenue: 16.0 feet
- St. Clair Avenue: 15.1 feet
- Superior Avenue: 15.6 feet
- Payne Avenue: 15.0 feet
- Chester Avenue: 15.4 feet
- Euclid Avenue: 16.5 feet
- Prospect Avenue: 15.7 feet
- Carnegie Avenue: 16.1 feet
- Cedar Avenue: 21.1 feet
- East 22nd Avenue: 15.0 feet

For both Build alternatives, the existing mainline pavement needs to be widened 4.75 feet to accommodate the additional SmartLane traveled lane. This widening allows for the traveled lanes to shift away from the median barrier enough to then develop the SmartLane adjacent to the inside shoulder. Because of this widening to the outside, only the overhead bridges within the SR 2 Curve limits introduce a reduction in the minimum vertical clearance over I-90 WB. Outside of the SR 2 Curve, the outside edge, when widened, is lower than the existing and increases the vertical clearance at the outside edge of pavement.

Figure 12 shows a graphical representation of the proposed typical section along I-90 WB under the SR 2 bridge. The 4.75 feet of widening pushes the outside edge of pavement up an additional 0.209 feet when the 4.4% cross slope is extended. At the same time, the overhead profile of SR 2 is dropping at a rate of 0.75%, reducing the vertical clearance over the I-90 pavement by 0.036 feet. When combined with the I-90 WB outside edge of pavement elevation increase due to the widening, the total vertical clearance reduction is 0.245 feet. Subtracting this value from the existing vertical clearance of 15.06 feet as determined by the survey yields a **proposed minimum vertical clearance of 14.82 feet** at the SR 2 bridge.

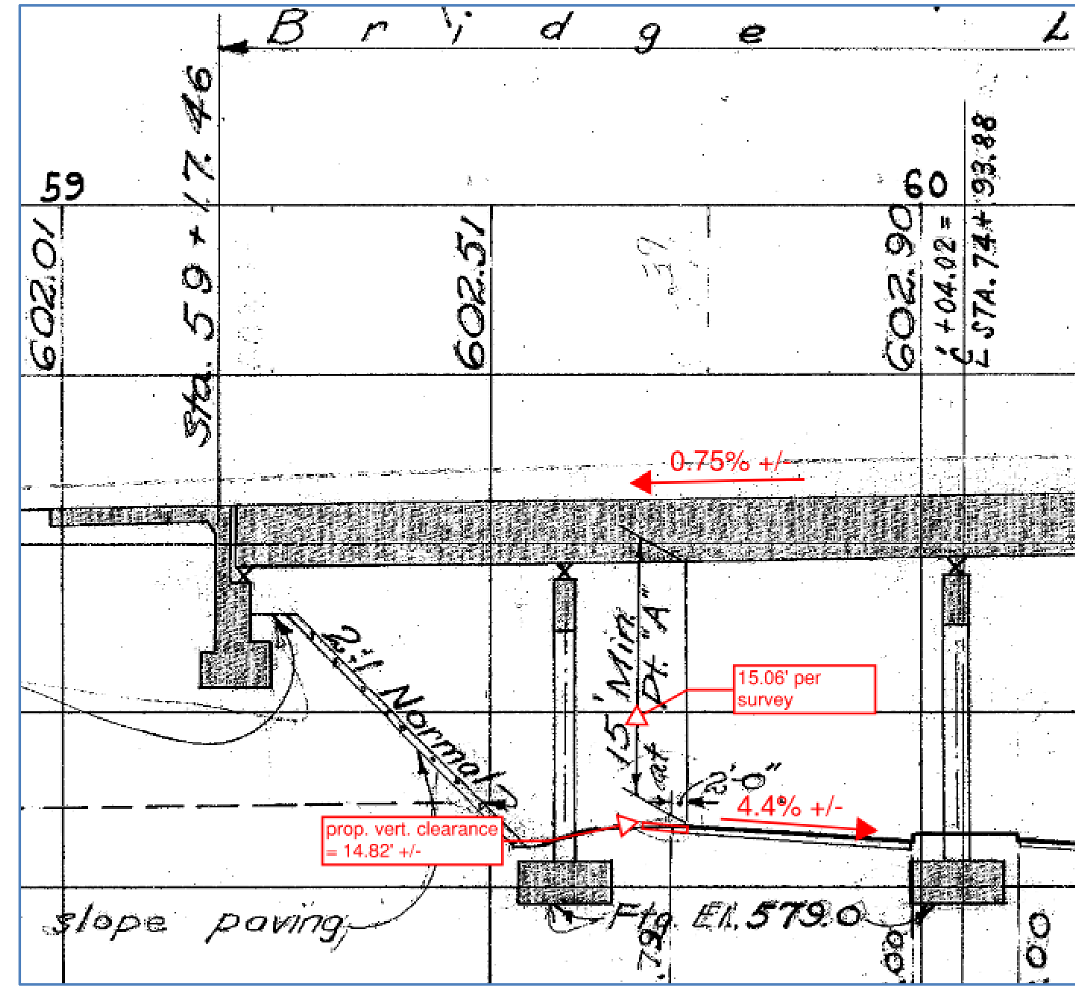

Figure 12 – Graphical representation of the proposed typical section under SR 2 bridge

This reduction in vertical clearance needs to be confirmed if this alternative is pursued using detailed survey showing the existing vertical clearance, lateral clearance, profile grade of SR 2 over I-90, and the exact location of the I-90 WB traveled lanes under the SR 2 bridge. It should be noted that this proposed vertical clearance of 14.82 feet exceeds the minimum 14.5 feet standard as specified in the L&D Volume 1 and is also greater than the minimum vertical clearance of 14.7 feet under the NS Railroad bridge. A design exception would be required for vertical clearance when at least 16.0 feet, meeting standards per L&D Volume 1, Figure 302-2, isn't provided.

<u>*Interchange Ramp Geometry*</u> – The interchange ramp geometry, including gore length, back of gore width, entrance/exit curve radius, and HSSD, was evaluated for both alternatives. ***Table 5*** summarizes the results of the interchange ramp geometry as the general-purpose lanes are shifted to the outside and the ramps were adjusted to meet the new location of the outside I-90 WB lane.

Table 5 – Interchange Ramp Geometry Summary

Ramp Name	Condition	Gore Length (feet)		Back of Gore Width (feet)		First Curve		Horizontal SSD (feet) **	
		Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
Prospect Entrance	Merge	75	64	12	24	125-220 feet	140 feet	195	170
Prospect Exit	Drop*	90	63	24	24	302-170 feet	180 feet	200	165
Chester Entrance	Add*	90	110	18	24	190-350 feet	200 ft + spiral	270	220
Chester Exit	Drop*	150	150	25	24	1012-250 feet	1145-250 feet	N/A	N/A
Superior Entrance	Add*	140	147	17	23	6 deg	5 deg	N/A	N/A
Superior Exit	Drop	127	137	27	24	14 deg	6 deg	370	300
Lakeside Entrance	Merge (Stop)	63	58	15	24	240 feet	240 feet	280	260
SR-2 Entrance	Dual Add	110	68	25	24	150 feet	150 feet	170	150
SR-2 Entrance (re-aligned)	Dual Add	110	82	25	24	150 feet	230 feet	170	175

* Part of auxiliary lane
** Based on structures and barrier. Assumes guardrail and vegeatation do not impede driver's line of sight.

It was decided during the study that for *Alternative 1*, where the SmartLane begins west of SR 2, the transition of the general-purpose lanes to the outside would occur about 150 feet after the SR 2 EB entrance ramp enters. As a result, the changes to the SR 2 entrance ramp shown in the table do not apply to *Alternative 1*. All other ramp modifications would apply to both *Alternative 1* and *Alternative 2*. The last entry of ***Table 5*** references a re-aligned SR 2 entrance ramp. This was completed by introducing a gradual reverse curve configuration prior to the merge into I-90 WB to better align the ramp into the mainline. This re-alignment increased the proposed HSSD over the existing and increased the entering curve radius. For all other ramps between Lakeside Avenue and East 22nd Street, the HSSD was reduced slightly due to the position of the entering ramps closer to the bridge and wall obstructions that are present on the outside of the pavement. See ***Appendix F*** for the information shown in ***Table 5***.

<u>*SmartLane Sign Placement*</u> – Several options exist for how best to communicate whether the SmartLane is open or closed to the driving public. Large digital message signs (DMS) that span across the freeway and convey messages or smaller cantilever structures that may have more limited communication ability can be used. ***Figure 13*** shows a standard walk-in message board with full-width gantries that allow for access across the gantry into the board.

Figure 13 – Standard walk-in DMS

Figure 14 shows a DMS that spans the entire freeway mounted to a gantry that allows access across the freeway and the ability to work on the DMS that is mounted to the front. These allow maintenance activities to be performed on the DMS while accessing from behind on the gantry truss. These are used in several locations along the I-670 SmartLane corridor.

Figure 14 – Front-mounted DMS used on I-670 SmartLane

Figure 15 shows a cantilever message board. Two of these were utilized on the I-670 SmartLane corridor. These offer a lower-cost option to convey to the drivers when the SmartLane is open or closed. These require front access which means at least one travel lane closed during maintenance activities.

Figure 15 – Cantilevered DMS board used on I-670 SmartLane

For this study, standard walk-in DMS boards on full-width trusses and front-access cantilevered DMS boards were assumed. The placement of the gantries was assumed to be immediately after an entrance ramp and at the beginning of the SmartLane. When identifying whether to assume a full-width truss or a cantilevered sign, the deciding factor where a truss was required was if there was already guide signs located where it was anticipated a SmartLane sign needed to be placed. If an existing truss was located there, then it was assumed that the SmartLane message board could be combined onto a new ITS truss. If there were no overhead guide sign conflicts, then a cantilevered sign could be used. ***Appendix G*** shows the anticipated proposed overhead SmartLane sign locations. Using cantilever supports can be beneficial because they are cheaper than the full width truss supports, but they may not be an option in a few locations where there are existing static guide signs as they would block the static signs and would need to be combined on a sign truss. The placement of the controller for the DMS is difficult for a cantilever support that is mounted in the median like in Figure X because often the controller is on the outside and getting wiring to the sign is difficult. The trusses are more expensive but static signs can be mounted to them and the controller can be placed on the outside shoulder and wire directly to the DMS.

For this corridor, a balance was targeted to control costs but increase functionality while reviewing whether one option would be determined to not be possible. For example, one location, near Euclid Avenue, an existing retaining wall would likely make a truss infeasible. See ***Figure 16*** for a sketch of the assumed locations of and distances between the SmartLane signs. These are shown in ***Appendix G*** as well.

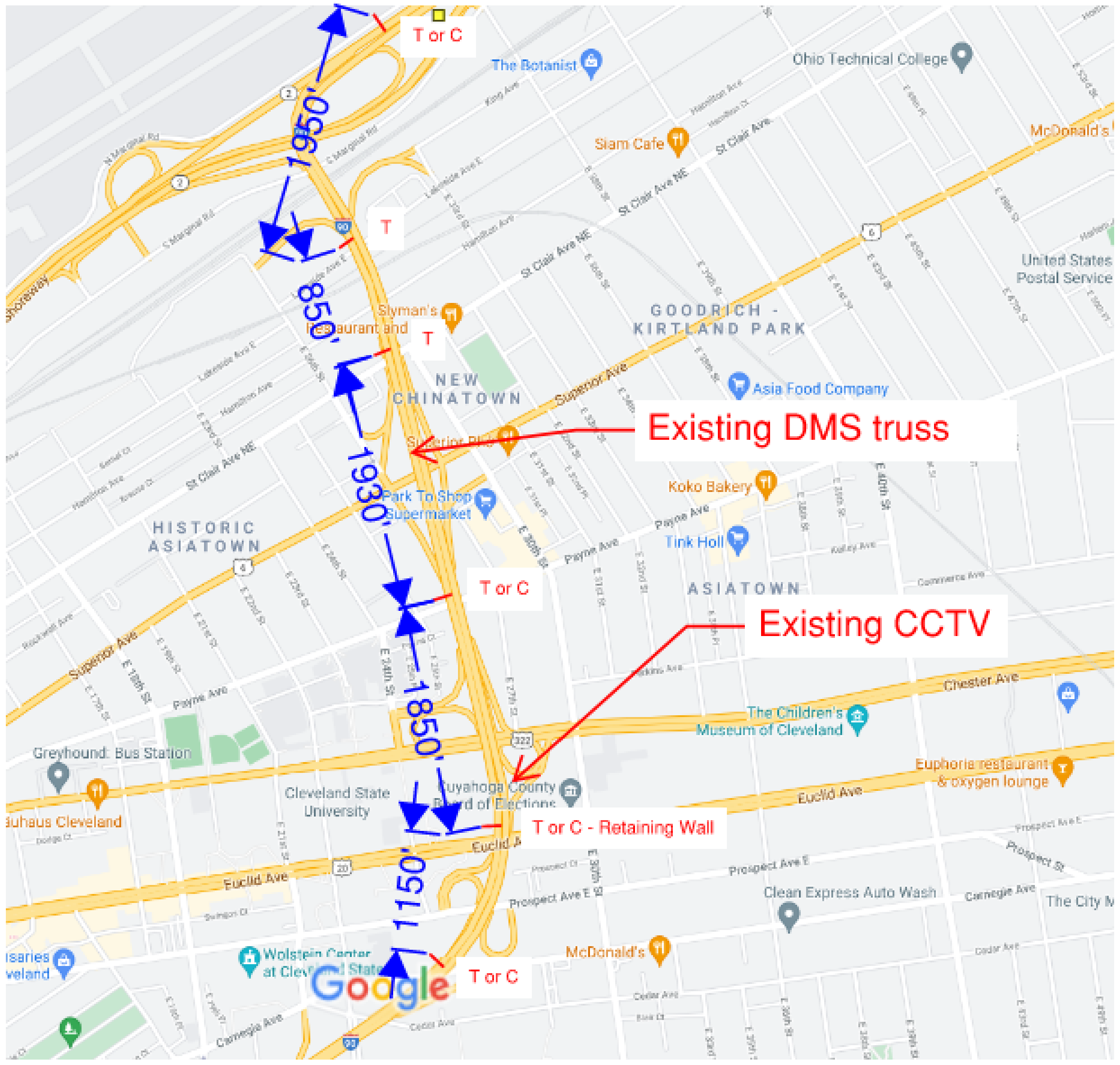

Figure 16 – Sketch of assumed SmartLane signs

The placement of these signs allows them to be utilized as a communication tool to drivers during construction of the Central Interchange project. That construction project, with potential to begin as early as 2024, is likely to introduce significant disruption to the traffic pattern along I-90 approaching the Central Interchange for several years. The presence of the DMS proposed in this study will likely offset the need and cost for portable message boards that would normally be used during the construction of that project.

Estimated Construction Costs

A construction cost estimate was prepared for the two Build alternatives. These construction cost estimates assumed that the big-ticket items, such as pavement areas, curb, barrier, retaining walls, overhead gantries, and digital message signs were quantified using CADD areas. Other items, such as drainage, earthwork, traffic control, and maintenance of traffic (MOT), were reported as a raw percentage of the total construction cost or based on similar projects due to the lack of detailed design completed at this time. The cost estimate utilized 2020 bid tabs for unit costs, and the entire estimate was inflated for 2025 year of construction using an inflation percentage increase of 16.0%. A 30% contingency was applied to the construction cost subtotal due to the level of uncertainty that still exists with the design.

CHAPTER 5: COMPARISON OF ALTERNATIVES

The two Build alternatives were compared based on the following categories:

- Safety Performance
- Traffic Operations
- Adherence to Geometric Standards
- Estimated Construction Costs

Safety Performance – This category evaluates the improvement to the safety performance for each alternative. Using the methodologies in the *Highway Safety Manual* (HSM) through ODOT's Economic Crash Analysis Tool (ECAT), the safety performance for three scenarios were evaluated - *No Build*, *Build with SmartLane Closed*, and *Build with SmartLane Open.* The predicted crash frequencies for the *No Build*, *Build with SmartLane Closed*, and *Build with SmartLane Open* conditions are summarized in ***Table 6***. ECAT output and calculations are included in ***Appendix C***. Note that these are predicted crash frequencies and existing crash data was not incorporated into this analysis. "Alternative 1" denotes the SmartLane starting west of the SR 2 interchange while "Alternative 2" includes the SmartLane starting east of the SR 2 interchange.

Table 6: HSM Analysis Results

	Crashes Per Year				
	Fatal and Serious Injury	**Minor Injury**	**Possible Injury**	**No Injury**	**Total**
No Build	2.75	8.86	9.76	62.46	83.83
Build (with SmartLane Open and Closed) Alternative 1	2.45	7.61	8.26	50.13	68.45
Build (with SmartLane Open and Closed) Alternative 2	2.06	6.27	6.74	36.79	51.86

Both Build alternatives offer significant improvement over the No-Build alternative. However, the combination of the closer proximity of the SmartLane to the median barrier and the congestion resulting from not addressing the issues through the SR 2 interchange makes Alternative 1 perform much worse than Alternative 2. With the capacity improvement through the bottleneck in the corridor, the congestion-related crashes are expected to be reduced, allowing Alternative 2 to score the best in this category.

Traffic Operations – This category evaluates the anticipated improvement in the vehicular traffic operations for each alternative. The biggest capacity constraint in the I-90 WB corridor is the two-lane mainline segment through the SR 2 interchange. Starting the SmartLane east of this interchange (*Alternative 2*) will provide an additional lane through this pinch point and provide a significant improvement in operations for the entire corridor. Starting the SmartLane west of the interchange (*Alternative 1*) will not provide any benefit to the pinch point and ultimately provides very little benefit to the rest of the corridor. The capacity analysis shows that any improvement for the corridor needs to address the capacity through the SR 2 interchange. For this reason, *Alternative 2* performs considerably better than *Alternative 1*.

Adherence to Geometric Standards – This category evaluates the ability to meet geometric standards established for freeways and ramps in ODOT's Location and Design (L&D) Manual, Volume 1. Several sub criteria were evaluated, including lane and shoulder width, horizontal stopping sight distance (HSSD), vertical clearance, lateral clearance, and interchange ramp geometry. The two Build alternatives have the same function, proposed typical section, and footprint west of SR 2. The difference between these two alternatives in this category is isolated to the SR 2 interchange. With the narrow opening under the existing SR 2 bridge over I-90, *Alternative 2* creates additional impacts due to reduced vertical clearance, lateral clearance, and HSSD through this curve and under this bridge than *Alternative 1*. For this reason, *Alternative 1* scores better than *Alternative 2*.

Construction Cost Estimate – ***Table 7*** shows the estimated construction costs for the two Build alternatives. Refer to ***Appendix H*** of this report for the Construction Cost Estimates for each Build alternative. While *Alternative 2* is estimated to cost nearly $4M more than *Alternative 1*, the capacity and safety benefits of introducing the additional I-90 WB lane through the SR 2 interchange make that additional cost valuable, as shown by the minimal capacity benefit *Alternative 1* has over the *No-Build* alternative and the significant capacity and safety improvement *Alternative 2* has over *Alternative 1*.

Table 7 – Estimated Construction Costs for the Build Alternatives (2025 dollars)

Alternative Number and Name	Construction Cost (2025 dollars)
Alternative 1 – SmartLane West of SR 2 Start	$9.92M
Alternative 2 – SmartLane East of SR 2 Start	$13.79M

Refer to ***Appendix I*** of this report for the Evaluation Matrix, also shown in ***Figure 17***, that was developed for this project and compares these alternatives.

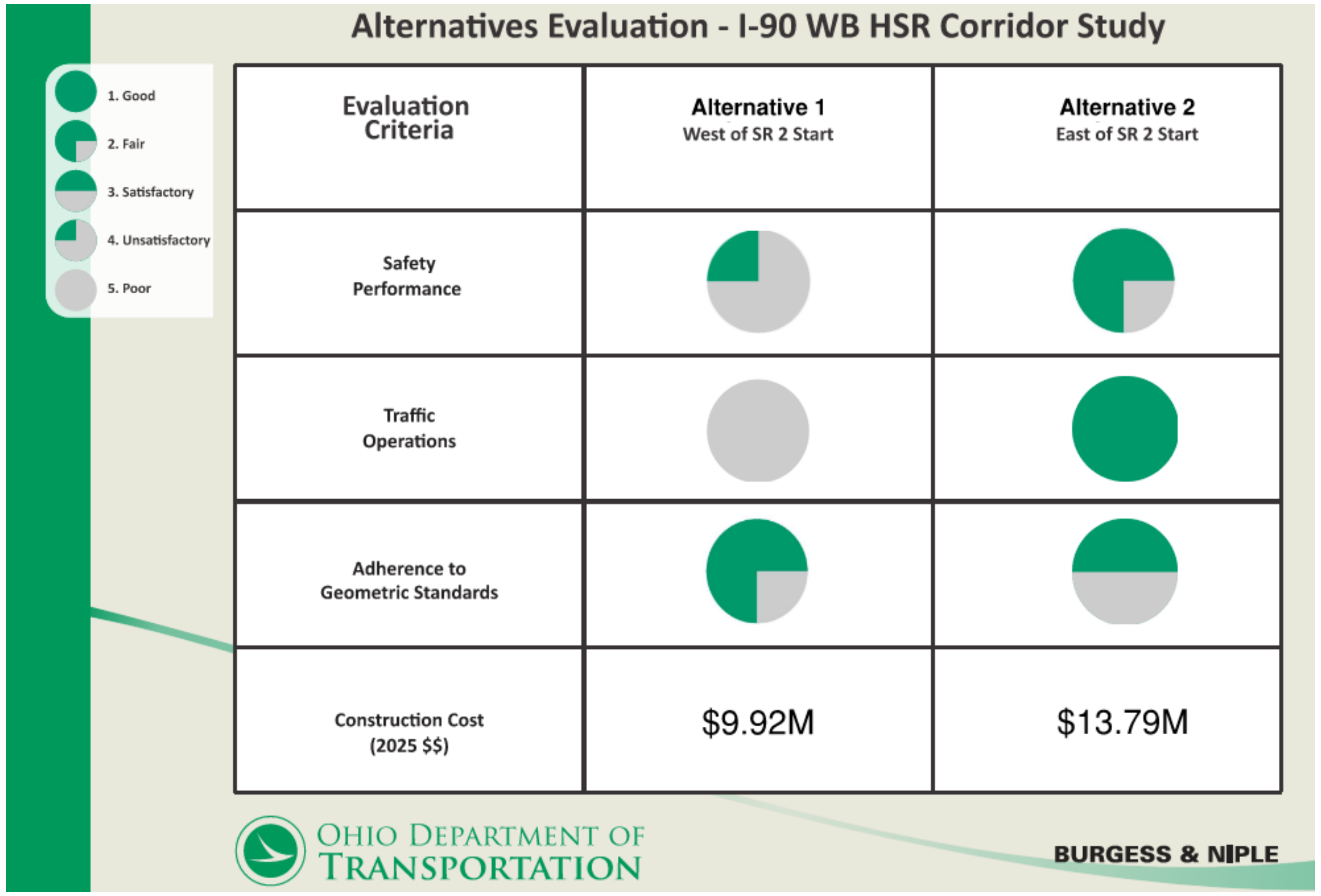

Figure 17 – Evaluation Matrix

CHAPTER 6: COORDINATION SUMMARY

Extensive coordination with ODOT occurred during this study. Two coordination meetings occurred with ODOT District 12 staff to identify goals of this study, discuss the alternatives, and identify the areas to target during the analysis and evaluation of each alternative. A third coordination meeting occurred with ODOT District 12 and ODOT Office of Roadway Engineering (ORE) to confirm the alternatives that were carried forward into this final report. Refer to ***Appendix J*** for the meeting minutes summary for these meetings. Here is a summary of the meetings that occurred with ODOT staff:

- **Meeting #1** (January 19, 2021 via Microsoft Teams virtual platform) – this meeting was with ODOT District 12 and the Study Team. The purpose of this meeting was to provide an overview of the study and identify collaboratively the potential alternatives to evaluate as part of this study. This meeting served as an early check-in with ODOT staff as the Study Team began evaluating both the Inside SmartLane and the Outside SmartLane alternatives. During this meeting, it was collectively determined to eliminate the right-side (outside) SmartLane alternative from further consideration due to the number of interchange ramps and the complexity with providing a part-time lane without creating additional driver confusion.
- **Meeting #2** (May 6, 2021 via Microsoft Teams virtual platform) – this meeting was a project update meeting with ODOT District 12 and the Study Team. The purpose of this meeting was to provide a status update on the study and specifically discuss the anticipated changes to the ramp geometry with the general-purpose lanes being shifted to the outside away from the median barrier. The goal of this meeting was to confirm that the inside SmartLane alternative had enough merit to advance further by completing the analysis and cost estimates. It was decided during this meeting that two variations of the left-side (inside) SmartLane strategy would be evaluated: one that starts the SmartLane west of SR 2 (*Alternative 1*) and one that starts the SmartLane east of SR 2 (*Alternative 2*). It was requested by ODOT to evaluate these two alternatives in order to determine if the additional costs and impacts of pushing an additional travel lane along I-90 WB through the SR 2 interchange would offer enough of a benefit to make it worthwhile.
- **Meeting #3** (May 12, 2021 via Microsoft Teams virtual platform) – this meeting was a project update meeting with ODOT ORE, ODOT District 12, and the Study Team. The purpose of this meeting was to provide a status update on the study and specifically discuss the anticipated changes to the ramp geometry with the general-purpose lanes being shifted to the outside away from the median barrier and confirm that there were no fatal flaws that ORE saw with the proposed changes. This meeting also served to identify the critical items to evaluate as part of the analysis and what needed addressed as part of the narrative in the final summary report.

A DRAFT submittal of the proposed conceptual alternatives and costs were provided to ODOT for review on August 9, 2021. Comments were provided by ODOT. Those comments, as well as the Study Team's disposition to those comments are provided in ***Appendix K***.

CHAPTER 7: CONCLUSION AND NEXT STEPS

I-90 WB experiences significant daily congestion during the PM peak period of 4-7pm from East of 55th Street through the Innerbelt Curve and Innerbelt Trench to I-77. This is resulting in a lot of rear-end and sideswipe passing crashes, generally associated with congested conditions. Short-term, low-cost capacity improvements were evaluated to add capacity through this corridor. These improvements included the addition of a SmartLane, like what was constructed recently along I-670 EB from downtown Columbus to the I-270 outerbelt. SmartLane is the ODOT-named initiative of using the shoulder as a part-time lane to address congestion concerns. The shoulder is used as a lane during peak periods of congestion when needed, then returned to a shoulder during non-peak periods of congestion. Changeable message boards are used to communicate to drivers when it is appropriate to use the part-time shoulder lane and typically numerous cameras are placed along the corridor to allow for operators to monitor the SmartLane corridor remotely for any obstructions that may be in the shoulder lane. While these improvements may appear to be short term, there is not a commitment to the long-term improvements at this time because of the uncertainty of available funding for future construction projects that are expected to significantly change the alignment and proposed typical section of I-90 through the Innerbelt Trench (East 22nd Street to the SR 2 interchange) and Innerbelt Curve (SR 2 interchange). It is also possible that the improvements specified as part of this study could greatly improve traffic flow and wayfinding during construction of the future construction projects.

Two Build SmartLane alternatives, developed to improve the congestion and the safety performance through this section of I-90 WB, were evaluated. Both alternatives utilized an inside (left side) SmartLane by shifting the general-purpose lanes to the outside then starting the SmartLane on the inside. The difference between the two Build alternatives is where the SmartLane begins. **Alternative 1** (*West of SR 2 Start*) begins the SmartLane west of the entrance ramp from SR 2 EB. This alternative maintains the existing two lanes along I-90 WB through the SR 2 interchange. **Alternative 2** (*East of SR 2 Start*) begins the SmartLane east of the SR 2 interchange between East 55th Street and SR 2. This alternative adds an additional lane of capacity through the SR 2 interchange.

An Evaluation Matrix is included in this report that summarizes graphically the comparative analysis between the two Build alternatives. Each alternative was compared based on the following categories:

- Safety Performance
- Traffic Operations
- Adherence to Geometric Standards
- Construction Cost

A construction cost estimate was prepared for the two Build alternatives.

The purpose of the study is to identify alternatives that reduce the congestion along the I-90 WB corridor from the SR 2 interchange to the I-77 interchange. Based on the results of the analysis and what is shown in the Evaluation Matrix, both alternatives show a noticeable benefit over the *No-Build* alternative with respect to safety performance. The total crash frequency decreased in every severity type for both Build alternatives. However, *Alternative 2* shows significantly better results than *Alternative 1* because it alleviates the congestion at the major bottleneck in the corridor, the SR 2 interchange. It reduces the predicted crash frequency of the fatal, serious injury, minor injury and possible injury crashes. For this reason, *Alternative 2* scores the best in this category.

With respect to Traffic Operations, the biggest capacity constraint in the I-90 WB corridor is the two-lane mainline segment through the SR 2 interchange. Starting the SmartLane east of this interchange (*Alternative 2*) will provide an additional lane through this pinch point and provide a significant improvement in operations for the entire corridor. Starting the SmartLane west of the interchange (*Alternative 1*) will not provide any benefit to the pinch point and ultimately provides very little benefit to the rest of the corridor. The capacity analysis shows that any improvement for the corridor needs to address the capacity through the SR 2 interchange. For this reason, *Alternative 2* performs considerably better than *Alternative 1*.

Both Build alternatives were compared based on their ability to adhere to geometric standards. Several sub criteria were evaluated, including lane and shoulder width, horizontal stopping sight distance (HSSD), vertical clearance, lateral clearance, and interchange ramp geometry. The two Build alternatives have the same function, proposed typical section, and footprint west of SR 2. The difference between these two alternatives in this category is isolated to the SR 2 interchange. With the narrow opening under the existing SR 2 bridge over I-90, *Alternative 2* creates additional impacts due to reduced vertical clearance, lateral clearance, and HSSD through this curve and under this bridge than *Alternative 1*. For this reason, *Alternative 1* scores better than *Alternative 2.*

The estimated construction cost *Alternative 1* is $9.92M and for *Alternative 2* is $13.79M in 2025 construction dollars. While *Alternative 2* is estimated to cost nearly $4M more than *Alternative 1*, the capacity and safety benefits of introducing the additional I-90 WB lane through the SR 2 interchange make that additional cost valuable, as shown by the minimal capacity benefit *Alternative 1* has over the *No-Build* alternative and the significant capacity and safety improvement *Alternative 2* has over *Alternative 1.*

Upon review of the Build alternatives, *Alternative 2* is the highest performing alternative with respect to capacity improvement and safety performance. This alternative addresses the capacity bottleneck that exists through the I-90 WB corridor at the SR 2 interchange. Due to its ability to reduce the congestion and improve the safety performance through the corridor, ***Alternative 2* is determined to be the Recommended Alternative to carry forward into the next phase of project development based on the analysis completed as part of this study.**

TIMING OF IMPLEMENTATION

This study was developed assuming that the SmartLane would be implemented after the Central Interchange construction was completed, as the southern terminus described in this report indicates matching into the proposed typical section that is being constructed as part of CCG3 under East 22nd Street. This improvement is expected to be a short-term solution to address the capacity issues through the Trench and Curve sections until construction funding becomes available for the long-term solutions.

However, it makes sense to implement the SmartLane as proposed in this study as soon as possible, even before or during the CCG3 construction. The traffic models show that the capacity pinch point along I-90 WB is through the SR 2 curve due to the number of existing lanes and through the trench due to the number of ramp accesses along this section. The right-hand lane through the corridor acts as a long auxiliary lane for traffic accessing the ramps at SR 2, Lakeside, Superior, Prospect, and Chester, which doesn't allow much capacity of that lane to be devoted to traffic traveling through the corridor. This forces most of the through traffic to utilize the left-hand two lanes, overloading them and creating significant congestion. Adding the additional lane as part of the SmartLane would offer an additional lane for this high volume through traffic. If this was implemented prior to the construction of CCG3.

If the SmartLane was implemented before CCG3 construction, the proposed additional lane would make four lanes under Carnegie and East 22nd Street that would match into the existing four lanes west of East 22nd Street that is created by the development of the drop lane to I-77 SB. In this situation, the SmartLane would continue west along I-90 as a General-Purpose lane and the right-hand lane would become a drop to I-77 SB. This would introduce a weave along I-90 WB between the Prospect entrance ramp and the exit to I-77 SB that would need to be analyzed. This would also require Design Exceptions to be filed for shoulder width under the overhead bridges and HSSD deficiencies under the Carnegie overhead bridge.

Regardless whether the SmartLane is implemented before or during construction of CCG3, the conceptual MOT that has been developed for CCG3A should be reviewed to determine when the SmartLane would need to be closed. Certain construction phases of CCG3 have reduced the lanes along I-90 WB or I-77 SB, making it inappropriate to have the additional lane created by the SmartLane along I-90 through the trench. At first glance, it appears that the SmartLane would need to be closed during Phase 5 and Phase 6, as shown in the Conceptual MOT for CCG3A that is shown in ***Appendix L*** of this report. Lateral widths would need to be reviewed to determine if the SmartLane could be open during Phase 7 through Phase 10. A detailed review of the CCG3A MOT should be completed to determine the worth of implementing the SmartLane prior to or during CCG3 construction.

NEXT STEPS

Depending on which alternative described in this study is carried forward into the next phase of project development, further investigation and information gathering may be necessary to confirm impacts and meet the needs established by the ODOT Project Development Process. Here are our recommendations for next steps:

- Complete additional capacity analysis and stakeholder engagement to determine if it is feasible to close the existing Lakeside Avenue to I-90 WB entrance ramp
- Complete additional capacity analysis and stakeholder engagement to determine if it is feasible to reduce the existing SR 2 EB to I-90 WB entrance ramp to a single lane if the Lakeside Avenue entrance ramp can't be closed
- Complete the NEPA Document confirming the Preferred Alternative,
- Obtain detailed survey or mobile scan to obtain lateral clearance for the overhead bridges over I-90 from the SR 2 interchange to the East 22nd Street bridge to confirm the proposed lane configuration fits,
- Obtain detailed survey or mobile scan to obtain the existing minimum vertical clearance over I-90 from the SR 2 interchange to the East 22nd Street bridge to confirm that widening I-90 doesn't introduce a vertical clearance deficiency,
- Obtain detailed mapping of the existing utilities in the corridor,
- Confirm that the I-271 to I-480 corridors would be an acceptable alternative interstate route that provides 16 feet vertical clearance,
- Draft the Design Exceptions for vertical clearance, lateral clearance, and HSSD deficiencies as a result of the chosen alternative,
- Develop detailed horizontal and vertical geometry of the chosen alternative,
- Evaluate the tradeoffs between lane width and shoulder width through the SR 2 curve, and
- Evaluate options to maximize the acceleration length of the Prospect to I-90 WB entrance ramp when connecting to the proposed CCG3 project.
- If desired to implement SmartLane prior to CCG3, evaluate the operation of the weave along I-90 between Prospect and I-77,
- Draft the Design Exceptions for shoulder width under the overhead bridges and HSSD under the Carnegie overhead bridge, and
- Review the CCG3A Conceptual MOT to determine specifically the anticipated construction phases and duration that the SmartLane would need to be closed due to lane reductions along I-90 and I-77 west of East 22nd Street during construction, and
- Coordination should occur with the TMC to ensure that expectations are realistic that their operators can adequately manage the additional coverage and oversight in areas of reduced HSSD.