Manual Revisions and Tool Compatibility

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Change Description</th>
<th>Virginia iCAP Tool Version Compatibility</th>
<th>VJuST Version Compatibility</th>
<th>TOSAM Version Compatibility</th>
</tr>
</thead>
</table>

Copyright

The contents of all material available in this manual and its online version are copyrighted by the Virginia Department of Transportation (VDOT) unless otherwise indicated. Copyright is not claimed as to any part of an original work prepared by a U.S. or state government officer or employee as part of that person’s official duties, or any information extracted from materials disseminated by a private manufacturer. All rights are reserved by VDOT, and content may not be reproduced, downloaded, disseminated, published, or transferred, in any form or by any means, except with the prior written permission of VDOT or as indicated in this manual. Copies for personal or academic use may be downloaded or printed, consistent with the mission and purpose of VDOT (as codified in its governing documents). However, no part of such content may be otherwise or subsequently reproduced, downloaded, disseminated, published, or transferred, in any form or by any means, except with the prior written permission of and with express attribution to VDOT. Copyright infringement is a violation of federal law subject to criminal and civil penalties.
Technical Working Group

VDOT created a technical working group (TWG) to collaborate in the development of the Virginia Intersection and Interchange Control Assessment Program (iCAP). The TWG consisted of public and private sector engineers, designers, and transportation planners from around Virginia. This team was charged with developing the Informational and Instructional Memorandum (IIM), associated tool, and this Virginia iCAP Manual. This manual was based on current VDOT policies and guidelines, industry best practices, and research findings. The following individuals were involved in the development of the Virginia iCAP materials.

**VDOT**
- Sanhita Lahiri, Traffic Operations Division (Project Manager)
- Mena Lockwood, Traffic Operations Division
- Stephen Read, Traffic Operations Division
- Matt Bonacci, Traffic Operations Division
- Ryan "Ma’in" Krunz, Traffic Operations Division
- Ben Mannell, Transportation and Mobility Planning Division
- George Rogerson, Location and Design Division
- Federico Gontaruk, Location and Design Division
- Huanyu “Allan” Yue, Location and Design Division
- Rob Hofrichter, Office of Land Use
- Anne Booker, Salem District
- Sean Nelson, Culpeper District

**Federal Highway Administration (FHWA)**
- Karen King, Highway Safety Engineer and Local Assistance Programs Coordinator
- Mour Diop, Environmental Protection Specialist

**Consultant Team**
- Tim White, Kimley-Horn
- Andy Nagle, Kimley-Horn
- Caitlin Kovel, Kimley-Horn
- Jack Iffert, Kimley-Horn
- Andrew Williams, Kimley-Horn
- Kirsten Tynch, VHB
- Michelle Cavucci, VHB
- Sean Becker, VHB
- Mike Tantillo, VHB
- Virginia O’Connor, ToXcel
- Gaby Cross, ToXcel

**Virginia Intersection and Interchange Control Assessment Program Champion**
- Kenneth King, VDOT, Salem District
# Table of Contents

**Chapter 1. Virginia iCAP Background and IIM**

1.1 Overview of the Virginia iCAP IIM ................................................................. 1
1.2 Relationship to other VDOT Initiatives .......................................................... 1
  1.2.1 Innovative Intersections ........................................................................... 1
  1.2.2 Performance-based Planning Approach ................................................ 2
  1.2.3 Safe System Approach ........................................................................... 3
1.3 Manual Organization ....................................................................................... 3

**Chapter 2. Virginia iCAP Process**

2.1 Applicability ................................................................................................. 4
  2.1.1 Project Phases ....................................................................................... 6
  2.1.2 Project Location ..................................................................................... 6
  2.1.3 Project Purpose and Need .................................................................. 7
  2.1.4 Performance Based Practical Design ................................................ 7
  2.1.5 Applicability Documentation ............................................................... 8

2.2 Virginia iCAP Assessment Stage 1: Alternatives Screening ....................... 8
  2.2.1 Scoping Meeting ..................................................................................... 10
  2.2.2 Stage 1 Sketch and Cost Estimate ....................................................... 12
  2.2.3 Stage 1 Metric Performance Ranking ................................................ 13
2.3 Virginia iCAP Assessment Stage 2: Alternatives Assessment ....................... 13
  2.3.1 Stage 2 Operations and Safety Performance Evaluation ..................... 16
  2.3.2 Stage 2 Sketch and Cost Estimate ....................................................... 16

2.4 Reporting and Approvals ............................................................................. 18

**Chapter 3. Virginia iCAP Tool**

3.1 Instructions .................................................................................................. 19

3.2 Applicability and General Input Worksheet ................................................ 20
  3.2.1 Applicability Form .............................................................................. 20
  3.2.2 General Input Worksheet .................................................................. 20
3.3 Metric Weighting ......................................................................................... 23

3.4 Stage 1: Alternatives Screening ................................................................. 26
  3.4.1 Stage 1 Input Worksheet ..................................................................... 26
  3.4.2 Stage 1 Performance Matrix ............................................................... 28
  3.4.3 Stage 1 Metric Methodology ............................................................... 31
  3.4.4 Stage 1 Alternative Selection and Alternative Justification Guidance ... 34
3.5 Stage 2: Alternatives Assessment ........................................................................................................... 37
  3.5.1 Stage 2 Input Worksheet ....................................................................................................................... 37
  3.5.2 Stage 2 Performance Matrix ................................................................................................................. 43
  3.5.3 Stage 2 Metric Methodology .............................................................................................................. 45
  3.5.4 Stage 2 Alternative Selection and Justification .................................................................................. 48
3.6 Reporting ................................................................................................................................................. 48
3.7 Troubleshooting Tool Issues ................................................................................................................ 50

Chapter 4, Assessment Techniques and Strategies .................................................................................... 51

4.1 Partial and Hybrid Innovative Intersection Designs ............................................................................... 51
4.2 Analyzing Multiple Intersections ......................................................................................................... 52
4.3 Impacts to Adjacent Intersections ....................................................................................................... 53
4.4 Analyzing Five-Legged Intersections .................................................................................................. 53
4.5 Analyzing Multiple Peak Periods ........................................................................................................ 53

Appendices
Appendix A: Virginia iCAP Case Studies
Appendix B: Virginia iCAP Reviewers Prompt List
Appendix C: Virginia iCAP Tool Metric Scoring Methodology

List of Tables
Table 1: Virginia iCAP Stage 2 MOEs ........................................................................................................... 11
Table 2: Data Field Input Legend ................................................................................................................ 19
Table 3: Reference Data for Determining Virginia iCAP Metric Weightings ........................................ 24
Table 4: Virginia iCAP Tool Stage 1 Pedestrian Metric MOE Scoring Definition ..................................... 33
Table 5: Standard Number of Approaches for Interchange Configurations with Multiple Intersections ... 42
Table 6: Standard Number of Approaches for Innovative Intersections with Multiple Intersections ...... 43
List of Figures

Figure 1: The Safe System Approach .......................................................... 3
Figure 2: Virginia iCAP Process ........................................................................ 4
Figure 3: Virginia iCAP Applicability Flowchart ........................................... 5
Figure 4: VDOT Arterial Preservation Network (as of July 2023) .................... 7
Figure 5: Virginia iCAP Assessment Stage 1 Flowchart .................................... 9
Figure 6: Stage 1 Sketch Example (CAD) ........................................................... 13
Figure 7: Virginia iCAP Assessment Stage 2 Flowchart .................................... 14
Figure 8: Stage 2 Refined Sketch Example ...................................................... 17
Figure 9: Virginia iCAP Tool Enable Content Warning ................................... 19
Figure 10: Virginia iCAP Tool General Input Worksheet ................................ 20
Figure 11: Virginia iCAP Tool General Input Worksheet - Continued ............. 21
Figure 12: VDOT Pathways for Planning Tool Potential for Safety Improvement (PSI) Layers ...... 22
Figure 13: VDOT Pedestrian Safety Action Plan (PSAP) Interactive Mapping Tool ........................................ 22
Figure 14: VTrans Mid-term Needs and Priorities Bicycle Access Layer (as of June 2023) ................ 23
Figure 15: Traffic Operations Priority Metric Weighting ................................. 25
Figure 16: Safety Priority Metric Weighting .................................................... 25
Figure 17: Virginia iCAP Tool Stage 1 Input Worksheet .................................. 26
Figure 18: Virginia iCAP Tool Stage 1 Performance Matrix ......................... 28
Figure 19: Virginia iCAP Tool Stage 1 Performance Matrix - Continued .......... 29
Figure 20: Virginia iCAP Tool VJuST Results Import – Existing or Base Condition Configuration .......... 30
Figure 21: Virginia iCAP Tool VJuST Results Import - Alternative Configurations ........ 30
Figure 22: Stage 1 Scoring Methodology ...................................................... 31
Figure 23: Virginia iCAP Tool Traffic Operations Metric MOE Scoring ................ 32
Figure 24: Virginia iCAP Tool Example Total Possible Score and Stage 1 Score Example .......... 35
Figure 25: Export Selected Alternatives to Stage 2 Button ............................. 36
Figure 26: Virginia iCAP Tool Stage 2 Traffic Operations Input Worksheet ........ 38
Figure 27: Virginia iCAP Tool Stage 2 Traffic Operations Input Worksheet - Continued ........... 39
Figure 28: Virginia iCAP Tool Quadrant Intersection ETT Sheet ..................... 41
Figure 29: Virginia iCAP Tool Stage 2 Performance Matrix ......................... 44
Figure 30: Stage 2 Scoring Methodology ....................................................... 45
Figure 31: Stage 2 CMF Selection Guidance Flowchart ................................ 47
Figure 32: Export Virginia iCAP Assessment to PDF Button ......................... 48
Figure 33: Example Stage 2 Metric Performance Matrix Results .................... 49
Figure 34: Enable Events Button .................................................................. 50
Figure 35: Partial RCUT Example ................................................................. 51
Figure 36: Hybrid MUT/Thru-Cut Example ..................................................... 52

List of Equations

Equation 1: Stage 1 Traffic Operations Metric MOE Score Calculation ............ 32
Equation 2: Stage 1 Safety Metric Score Calculation .................................... 33
Equation 3: Stage 1 Cost Metric MOE Score Calculation .............................. 33
Equation 4: Stage 2 Volume-Weighted Delay Result Calculation ................... 45
Equation 5: Stage 2 Traffic Operations Metric MOE Score Calculation .......... 46
Equation 6: Stage 2 Safety Metric MOE Score Calculation ............................ 47
Equation 7: Stage 2 Cost Metric MOE Score Calculation .............................. 48
# List of Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>APN</td>
<td>Arterial Preservation Network</td>
</tr>
<tr>
<td>AMP</td>
<td>Arterial Management Plan</td>
</tr>
<tr>
<td>CAD</td>
<td>Computer-Aided Design</td>
</tr>
<tr>
<td>CGT</td>
<td>Continuous Green-T</td>
</tr>
<tr>
<td>CMF</td>
<td>Crash Modification Factor</td>
</tr>
<tr>
<td>DDI</td>
<td>Diverging Diamond Interchange</td>
</tr>
<tr>
<td>DLT</td>
<td>Displaced Left Turn</td>
</tr>
<tr>
<td>DMV</td>
<td>Department of Motor Vehicles</td>
</tr>
<tr>
<td>DTE</td>
<td>District Traffic Engineer</td>
</tr>
<tr>
<td>ETT</td>
<td>Experienced Travel Time</td>
</tr>
<tr>
<td>FHWA</td>
<td>Federal Highway Administration</td>
</tr>
<tr>
<td>HSM</td>
<td>Highway Safety Manual</td>
</tr>
<tr>
<td>iCAP</td>
<td>Intersection and Interchange Control Assessment Program</td>
</tr>
<tr>
<td>ICE</td>
<td>Intersection Control Evaluation</td>
</tr>
<tr>
<td>IIM</td>
<td>Instructional and Informational Memoranda</td>
</tr>
<tr>
<td>MAP-21</td>
<td>Moving Ahead for Progress in the 21st Century Act</td>
</tr>
<tr>
<td>MOE</td>
<td>Measures of Effectiveness</td>
</tr>
<tr>
<td>MUD</td>
<td>Michigan Urban Diamond</td>
</tr>
<tr>
<td>MUT</td>
<td>Median U-Turn</td>
</tr>
<tr>
<td>NHS</td>
<td>National Highway System</td>
</tr>
<tr>
<td>PBPD</td>
<td>Performance Based Practical Design</td>
</tr>
<tr>
<td>PCL</td>
<td>Partial Cloverleaf</td>
</tr>
<tr>
<td>PSAP</td>
<td>Pedestrian Safety Action Plan</td>
</tr>
<tr>
<td>PSI</td>
<td>Potential for Safety Improvement</td>
</tr>
<tr>
<td>QR</td>
<td>Quadrant Roadway</td>
</tr>
<tr>
<td>RCUT</td>
<td>Restricted Crossing U-Turn</td>
</tr>
<tr>
<td>SFOE</td>
<td>Signal and Freeway Operations Engineer</td>
</tr>
<tr>
<td>SPAT</td>
<td>Signal Phasing and Timings</td>
</tr>
<tr>
<td>SPUi</td>
<td>Single-Point Urban Interchange</td>
</tr>
<tr>
<td>STARS</td>
<td>Strategically Targeted Affordable Roadway Solutions</td>
</tr>
<tr>
<td>TMPD</td>
<td>Transportation and Mobility Planning Division</td>
</tr>
<tr>
<td>TOSAM</td>
<td>Traffic Operations and Safety Analysis Manual</td>
</tr>
<tr>
<td>TWG</td>
<td>Technical Working Group</td>
</tr>
<tr>
<td>V/C</td>
<td>Volume to Capacity</td>
</tr>
<tr>
<td>VDOT</td>
<td>Virginia Department of Transportation</td>
</tr>
<tr>
<td>VJuST</td>
<td>VDOT Junction Screening Tool</td>
</tr>
<tr>
<td>VJuST-C</td>
<td>VDOT Junction Screening Tool Cost Estimate Module</td>
</tr>
</tbody>
</table>
Chapter 1. Virginia iCAP Background and IIM

An essential part of the Virginia Department of Transportation (VDOT) mission is to plan, deliver, operate, and maintain its transportation network in a safe and efficient manner for all travel modes. The mission for the transportation network can only be accomplished if the intersections and interchanges within the network are planned, designed, and operated in a safe and efficient manner for all travel modes. Therefore, when an existing intersection is modified or a new intersection is proposed, the full range of control types probable for the location should be examined to achieve optimal intersection and interchange performance. Intersections and interchanges can connect routes between regional origins and destinations and provide local access to land uses such as businesses and residential communities. For the purposes of this manual, intersections are defined as junctions between two or more roads, and include interchange ramp termini.

VDOT envisions a holistic approach to existing and proposed intersection control, considering safety, accessibility, congestion, asset condition, mode choice, cost effectiveness, sustainability, and quality of life for all users. The goal is to arrive at optimal solutions based on objective performance metrics by consistent comparison of alternatives, and clear documentation of the rationales, and benefits/disadvantages of the proposed alternatives. Additionally, the goal is to provide increased awareness of innovative intersection and interchange solutions.

1.1 Overview of the Virginia iCAP IIM

According to the Federal Highway Administration (FHWA), Intersection Control Evaluation (ICE) is a data-driven, performance-based framework and approach used to objectively screen alternatives and identify an optimal geometric and control solution for an intersection. FHWA recommends that state agencies adopt an ICE methodology. VDOT has adopted principles from the FHWA ICE framework to establish the Virginia Intersection and Interchange Control Assessment Program (Virginia iCAP).

Instructional and Informational Memorandum, IIM-TOD-397: Virginia Intersection and Interchange Control Assessment Program (iCAP) Policy and Guidance, serves to convey VDOT’s goals to integrate holistic consideration of intersection control into VDOT business practices by providing a process, guidance, and performance-based approach to aid in selecting the optimal intersection control alternative that meets the purpose and need of each project. The memorandum requires for the Virginia iCAP process to be followed on VDOT-led studies (e.g., Project Pipeline, Strategically Targeted Affordable Roadway Solutions (STARS), Arterial Management Plan (AMP)) and outlines VDOT’s methodology for evaluating intersection control throughout the project development process. The Virginia iCAP process is best practice, and is therefore recommended, but not required, for localities and private developers to consider implementing when evaluating intersection control.

1.2 Relationship to other VDOT Initiatives

VDOT has several existing programs and memoranda that align with the Virginia iCAP goal to objectively screen alternatives and further identify optimal control solutions. The initiatives outlined in this section include performance-based methodologies to improve traffic operations and safety for all users.

1.2.1 Innovative Intersections

Control solutions considered during a Virginia iCAP assessment may include conventional and/or innovative intersection and interchange designs. Innovative designs modify vehicle, pedestrian, and bicycle movements at intersections to reduce delay, increase efficiency, and improve safety for all road users.
The VDOT Junction Screening Tool (VJuST) aids transportation engineers and planners in screening innovative intersection and interchange configurations that might be appropriate at a given location. VJuST includes the following intersection and interchange configurations:

**Intersection Designs**
- Bowtie
- Center turn overpass
- Continuous green-T (CGT)
- Displaced left turn (DLT)
- Echelon
- Median U-turn (MUT)
- Quadrant roadway (QR)
- Restricted crossing U-turn (RCUT)
- Roundabout
- Mini roundabout
- Single loop
- Split intersection
- Thru-cut

**Interchange Designs**
- Contraflow left
- Displaced left turn (DLT)
- Diverging diamond interchange (DDI)
- Double roundabout
- Michigan urban diamond (MUD)
- Partial cloverleaf (PCL)
- Single-point urban interchange (SPUI)
- Single roundabout

Design considerations for each innovative intersection and interchange configuration are provided in the VJuST tools. Additional information, including informational brochures and videos, are available on the VDOT Innovative Intersections website.¹

### 1.2.2 Performance-based Planning Approach

In 2012, the Moving Ahead for Progress in the 21st Century Act (MAP-21) was signed into law, which called for state and metropolitan planning processes to incorporate a performance-based approach to decision-making.² Since then, engineers and planners across the country have approached transportation projects with performance-based principles in mind. The Virginia iCAP process achieves the MAP-21 goal to evaluate projects based on an objective, outcome-based process. Additional performance-based programs in Virginia include SMART SCALE, AMP, STARS, and Project Pipeline projects, which could benefit from incorporating the Virginia iCAP process.

---

¹ [https://www.virginiadot.org/innovativeintersections/](https://www.virginiadot.org/innovativeintersections/)
² [https://ops.fhwa.dot.gov/plan4ops/performance_based.htm](https://ops.fhwa.dot.gov/plan4ops/performance_based.htm)
1.2.3 Safe System Approach

The Safe System approach, depicted in Figure 1, is founded on the principle that human mistakes and psychological limits are anticipated and should be accommodated. Similar to Vision Zero, the Safe System approach targets zero fatalities. The Safe System approach recognizes that human mistakes do lead to crashes, but the transportation system (roadways, post-crash care, vehicles) should be designed to prevent those mistakes from resulting in serious injury or death. The Safe System approach focuses on:

- Safety for all modes: transit, walking, and biking
- Safe vehicles, which are designed and regulated to minimize fatal and serious injury crash risk
- Speed reduction
- Road design to accommodate human mistakes
- Post-crash care

1.3 Manual Organization

This manual outlines how to conduct a Virginia iCAP assessment using the Virginia iCAP Tool. This manual consists of four chapters, which provide background, instructions, and guidance on how to use the Microsoft Excel®-based spreadsheet tool to assess unsignalized and signalized intersection and interchange configurations. This manual is organized into the following chapters:

- **Chapter 1** provides an overview of IIM-TOD-397 and its relationship to other VDOT initiatives
- **Chapter 2** provides an overview of the Virginia iCAP process
- **Chapter 3** introduces the assumptions, inputs, and reporting requirements to complete an assessment using the Virginia iCAP Tool
- **Chapter 4** details unique concepts related to alternatives analyses and types of potential intersection control, including innovative intersections
- **Appendices** include example case studies and other relevant details and forms

---

Chapter 2. Virginia iCAP Process

A Virginia iCAP assessment may be initiated for a variety of reasons including but not limited to safety, traffic operations, multimodal access, maintenance, and/or land access. If a Virginia iCAP assessment is required for a VDOT-led project based on the project location and purpose and need, an assessment should be conducted in the following stages to holistically determine the best intersection alternative that satisfies the project purpose and need.

- **Virginia iCAP Assessment Stage 1: Alternatives Screening** – Establish a list of viable intersection control strategies
- **Virginia iCAP Assessment Stage 2: Alternatives Assessment** – Evaluate alternatives to select preferred control strategy

An overview of the Virginia iCAP process is shown in Figure 2.

Figure 2: Virginia iCAP Process

2.1 Applicability

The Virginia iCAP Applicability Flowchart, shown in Figure 3 and described in the following sections, should be used as a reference to determine if a Virginia iCAP assessment is required. There are four applicability criteria for Virginia iCAP assessments:

- Study lead
- Project location
- Project purpose and need
- Performance-based practical design
Figure 3: Virginia iCAP Applicability Flowchart

**APPLICABILITY**

1. **Study Lead**
   - Virginia iCAP assessment is recommended, but not required.

2. **Locality/Developer**
   - Virginia iCAP assessment is required. Complete Virginia iCAP Applicability Form.

3. **A.1 Location**
   - Is the intersection or interchange located on VDOT’s Arterial Preservation Network (APN)?
     - Yes
   - A.1.1
     - Is the intersection or interchange located on VDOT’s Arterial Preservation Network (APN)?
       - Yes
       - A.1.2
         - Is the intersection or interchange located on a VDOT-maintained roadway and a signal is recommended?
           - Yes
           - A.1.3
             - Stage 1 Virginia iCAP assessment is required along with warrant study per IIM-TE-387. Complete Virginia iCAP Applicability Form.
             - No
             - A.1.4
               - Virginia iCAP assessment is recommended, but not required.
               - No

4. **A.2 Purpose and Need**
   - Does the intersection or interchange purpose and need indicate traffic control should be evaluated?
     - Yes
     - A.2.1
       - Does the intersection or interchange purpose and need indicate traffic control should be evaluated?
         - Yes
         - A.3.1
           - If signalized, can operational and safety issues be resolved with changes to signal phasing and timing?
             - Yes
             - A.4
               - Virginia iCAP assessment is required. Complete Virginia iCAP Applicability Form.
               - No
               - A.5
                 - Complete Virginia iCAP Tool General Input Worksheet and Conduct Scoping Meeting.
                 - No

5. **A.3 Performance Based Practical Design**
   - Virginia iCAP assessment is not required. Submit Virginia iCAP Applicability Form to DTE, or designee, for approval.

**LEGEND**

- Applicable Tool
- Applicable Reference Document (Manual, IIM, Form)

**Notes:**
1. Include coordination with a VDOT Signal and Freeway Operations Engineer (SFOE)
2. If initial screening of traffic volumes and crashes reveal a signal is not likely to be warranted, then the Virginia iCAP process and signal warrant study are not required.
2.1.1 Project Phases
A Virginia iCAP assessment should be performed at locations where new or alternative traffic control are considered on the APN as part of VDOT-led studies and projects. An assessment may be initiated in any of the four levels within the project development cycle. Per IIM-TOD-397, a Virginia iCAP assessment is required for projects in the operations and design level and is recommended for projects in the visioning and program level. Refer to VDOT Traffic Operations and Safety Analysis Manual, Version 2.0 (TOSAM), Table 32: Project Categorization Matrix, for additional information regarding project phase definitions.\(^4\)

- **Planning Phase: Visioning Level**
  - Small area plan
  - Network analysis

- **Planning Phase: Program Level**
  - Corridor study (e.g., AMP, STARS, Project Pipeline)
  - Intersection evaluation
  - Interchange alternatives analysis
  - Interchange access report

- **Implementation Phase: Operations Level**
  - Traffic impact analysis
  - Traffic signal optimization

- **Implementation Phase: Design Level**
  - Intersection design
  - Maintenance of traffic

2.1.2 Project Location
Virginia iCAP provides a consistent decision-making process for the selection of unsignalized and signalized intersection controls on the Arterial Preservation Network (APN).\(^5\) The APN, shown in Figure 4, is the state-maintained portion of the National Highway System (NHS) in Virginia, including some additional highways that facilitate connectivity. It is recommended to check the latest version of the APN map before evaluating Virginia iCAP assessment applicability.

For VDOT-lead projects or studies located off the APN where the roadway is VDOT-maintained and a signal is recommended, IIM-TOD-397 requires for a Virginia iCAP Stage 1 assessment to be conducted along with a warrant study per the latest version of IIM-TE-387.

Although not all projects off the APN require a Virginia iCAP assessment, it is recommended that a Virginia iCAP assessment be considered for all intersection analyses where intersection control is evaluated.

---

\(^4\) [https://www.virginiadot.org/business/resources/TOSAM.pdf](https://www.virginiadot.org/business/resources/TOSAM.pdf)

\(^5\) [https://vdot.maps.arcgis.com/apps/webappviewer/index.html?id=6a024b2739e44b5b8599d86aa3b2c6d7](https://vdot.maps.arcgis.com/apps/webappviewer/index.html?id=6a024b2739e44b5b8599d86aa3b2c6d7)
2.1.3 Project Purpose and Need

Applicability for a Virginia iCAP assessment is dependent on whether IIM-TOD-397 and the project purpose and need indicate intersection control should be evaluated. A purpose and need statement that clearly identifies the reason for evaluating the intersection should be developed for a Virginia iCAP assessment. TOSAM Section 9.1.2 provides guidance on how to develop a project purpose and need statement.

Preliminary traffic, safety, and multimodal data should be collected as outlined in Section 3.2.2 to support in defining the purpose and need. A partial list of project types that could have purpose and need statements indicating that intersection control should be evaluated include:

- Constructing a new interchange or intersection
- Making capacity improvements to an existing intersection, such as adding new ramps or abandoning/removing ramps from ramp termini
- Changing or modifying the existing intersection control type
- Converting a directional median opening to a full-access intersection
- Converting a T-intersection to an all-way movement intersection

IIM-TOD-397 includes examples of project types that involve the assessment of appropriate intersection configuration and traffic control. The IIM also includes examples of proposed improvements that may not require a Virginia iCAP assessment.

2.1.4 Performance Based Practical Design

The Virginia iCAP process affords the user flexibility to apply practical engineering judgment when selecting appropriate intersection control. For example, if the intersection can be improved with changes to traffic signal timing and/or phasing, a Virginia iCAP assessment is not required. Instead, the project manager should document the signal timing or phasing changes that will address the purpose and need and that the Virginia iCAP assessment isn’t required. Refer to IIM-LD-2556 for additional information on Performance Based Practical Design (PBPD).

2.1.5 Applicability Documentation

After reviewing the Virginia iCAP applicability requirements, each proposed location for assessment should be discussed with the VDOT District Traffic Engineer (DTE), or designee, to determine the need for a Virginia iCAP assessment. The Virginia iCAP Applicability Form should be submitted to document whether an assessment is required. The Applicability Form can be accessed in the Virginia iCAP Tool. See Section 3.2.1 for additional details and guidance regarding the Applicability Form. Appendix A includes five Virginia iCAP case studies that provide examples of determining applicability.

2.2 Virginia iCAP Assessment Stage 1: Alternatives Screening

Figure 5 outlines the Virginia iCAP assessment Stage 1 procedure, including data collection, alternatives screening, and performance ranking. The goal of Stage 1 is to screen potential alternatives that could address the project purpose and need. The analysis performed in Stage 1 will result in a list of multiple alternatives to be further analyzed in Stage 2.

Stage 1 traffic operations and safety screening should be performed using VJuST, which is used to identify viable intersection configurations based on the potential to reduce congestion and improve safety and pedestrian accommodations. VJuST also provides relative cost at a high level for each intersection configuration. The latest version of VJuST can be accessed from the VDOT Innovative Intersections website.7 Instructions for how to use VJuST are provided within the tool.

7 https://www.virginiadot.org/innovativeintersections/
The Virginia iCAP project team, including VDOT and stakeholder agency staff, will discuss which data is required to perform the alternatives screening. Operational analysis tools, performance metrics, and metric weighting should also be discussed at this meeting.

Scoping Meeting

1.1 Data Collection

1.1.1 Input data into Virginia iCAP Stage 1 Input Worksheet

1.2 Operations and Safety Initial Screening

1.2.1 Screen alternatives in VJuST

1.3 Stage 1 Sketch

1.3.1 Create Stage 1 sketch for potentially viable alternatives

1.4 Metric Performance Ranking

1.4.1 Evaluate and rank alternatives using the Virginia iCAP Tool Stage 1 Performance Matrix

1.5 Stage 2: Alternatives Assessment

LEGEND

Applicable Tool
2.2.1 Scoping Meeting

The Virginia iCAP policy applies to VDOT-led studies, e.g., Project Pipeline, STARS, AMP, other VDOT-led studies to support SMART SCALE applications, on roadway segments within the latest version of the APN. If a Virginia iCAP assessment is required, the project team should schedule a scoping meeting to discuss the purpose and need of improvement at the applicable intersections, data, analysis tools, performance metric weightings, and measures of effectiveness (MOEs) used to perform the assessment. VDOT and stakeholders, if applicable, should attend the scoping meeting. Stakeholders, including, but not limited to, the VDOT DTE, VDOT planning and traffic operations staff, the VDOT Signal and Freeway Operations Engineer (SFOE), locality stakeholders, and consultants, should attend the scoping meeting. It is important to engage all relevant stakeholders early in the study to gain concurrence and input throughout the evaluation process.

This section outlines topics that should be considered when scoping a project requiring a Virginia iCAP assessment. Additional details on initiating a Virginia iCAP assessment during each stage of the project development process are outlined in IIM-TOD-397. A detailed description of scoping considerations for traffic and safety analyses, including roles and responsibilities, is outlined in the VDOT TOSAM Chapter 9. Appendix B of the VDOT TOSAM includes a Project Scoping Meeting Preparation Form that should be referenced at the scoping meeting.

The VDOT TOSAM Chapter 9 includes topics that should be discussed at the scoping meeting. The project team should select analysis tools suitable for both evaluating intersections and producing the required MOEs. Section 9.1.7 of the VDOT TOSAM provides prompts to be considered during the scoping meeting including:

- Can the saturation level be determined based on traffic volumes alone?
- Do typical traffic conditions (reference probe data sources) indicate oversaturation? If so, microsimulation will be required.
- Are there project needs, such as need for visualization, that could drive the use of a more robust traffic analysis tool (e.g., are there expected alternatives that require microsimulation)?
- Is there a need for origin-destination data given travel patterns within the study area? If so, certain traffic analysis tools cannot be used given data limitations.
- What is the expected future demand? A currently undersaturated network could be oversaturated with future demand and thereby be unfit for deterministic analysis.
- Consider the goal of the project. What information needs to be conveyed?

If the project stakeholders anticipate that the preferred alternative(s) will require signalization, the group should also discuss the necessary processes to develop a signal justification report per IIM-TE-387.9

Study Limits

Virginia iCAP applies to intersections on the APN. The project team should document the study intersections requiring a Virginia iCAP assessment prior to the scoping meeting and refine the list during and/or after the meeting. The project team should review VDOT TOSAM Section 9.1.3 to identify considerations to help refine temporal and physical study limits.

Alternatives Analysis Assumptions

During the scoping meeting, the project stakeholders should understand the project purpose and need, data requirements, performance metric weightings, scenarios to be analyzed, MOEs needed, and analysis tools required to properly conduct an alternatives analysis for a Virginia iCAP assessment. In addition, the project team should review the data requirements for the Virginia iCAP assessment Stage 1 and Stage 2 processes outlined in Chapter 3.

---

8 Hyperlink to be added once published on the VDOT website.
DATA REQUIREMENTS
The project team should review VDOT TOSAM Chapter 6 to identify appropriate geometric, traffic, traffic signal operations, and other applicable data to be used in the Virginia iCAP assessment.

PERFORMANCE METRIC WEIGHTINGS
The project team and stakeholders should attain concurrence on the metric weightings to be used in the Virginia iCAP assessment and attain approval of the metric weightings by the VDOT DTE or designee. Metric weightings for the four performance metrics, traffic operations, pedestrian, safety, and cost, should be based on the project purpose and need. Section 3.3 provides additional guidance for selecting appropriate metric weightings.

ANALYSIS SCENARIOS
Multiple analysis scenarios may be considered during a Virginia iCAP assessment. Temporal limits of the project, such as peak hours and forecast year(s), should be defined based on the project purpose and need. Temporal limits should be discussed at the scoping meeting and if needed, refined after the meeting once data is collected and summarized. The forecast horizon year(s) should be selected based on project type, as outlined in the VDOT Traffic Forecasting Guidebook\(^\text{10}\) and consistent with IIM-TMPD-7.0.\(^\text{11}\) VJuST should be completed using volumes for the horizon year and future no-build traffic volumes must be developed prior to conducting a Virginia iCAP assessment.

MEASURES OF EFFECTIVENESS AND TOOL SELECTION
Stage 2 operations and safety performance must be evaluated using appropriate traffic operations MOEs and analysis tools per the VDOT TOSAM. The selection of traffic operations MOEs should be based on the project purpose and need following the process that is outlined in the VDOT TOSAM Section 4.1 and Section 9.2. The Virginia iCAP Tool is compatible with six traffic operations MOEs most used for decision-making at intersections and interchanges. The Stage 2 traffic operations MOEs are presented in Table 1 and are grouped in one of three categories.

Table 1: Virginia iCAP Stage 2 MOEs

<table>
<thead>
<tr>
<th>Stage 2 Traffic Operations MOE Category</th>
<th>Stage 2 Traffic Operations MOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay</td>
<td>• Control delay</td>
</tr>
<tr>
<td></td>
<td>• Microsimulation delay</td>
</tr>
<tr>
<td></td>
<td>• Experienced travel time (ETT)</td>
</tr>
<tr>
<td>Queue length</td>
<td>• 95(^{th}) percentile queue length</td>
</tr>
<tr>
<td></td>
<td>• Maximum queue length</td>
</tr>
<tr>
<td>Volume-to-Capacity (v/c) ratio</td>
<td>• V/C ratio</td>
</tr>
</tbody>
</table>

Note that ETT is not specifically selected as an MOE in the Virginia iCAP Tool. The ETT MOE is used to compare to control delay or microsimulation delay for any configurations that reroute vehicles.

The project team should select two traffic operations MOEs from the six MOEs available for iCAP assessments. The project team should select at most one traffic operations MOE from each category. Selecting two traffic operations MOEs from the same category, such as 95\(^{th}\) percentile queue length and maximum queue length, limits the project team’s ability to compare alternatives holistically.

The selection of analysis tool(s) used for a Virginia iCAP Stage 2 assessment is influenced by which traffic operations MOEs are chosen, along with other factors such as saturation, complex geometry,


\(^{11}\) https://www.virginiadot.org/business/resources/IIM/TMPD-7.0_Traffic_Forecasting.pdf
specific origin-destination patterns, or expected future demand and travel patterns. Per the VDOT TOSAM Section 9.2.2 analysis tools for Stage 2 may only be selected once MOEs are selected. TOSAM Table 2 should be referenced to determine what MOEs are acceptable to report for a given traffic analysis tool.

Section 3.5.3 includes guidance for selecting appropriate Crash Modification Factors (CMF) for the safety metric.

**Public Involvement**

Though not required for a Virginia iCAP assessment, public participation and public involvement are important efforts in establishing the project purpose and need and attaining input on the potential advantages and disadvantages of proposed transportation alternatives. Thoughtful and effective public involvement supports the Virginia iCAP goal to holistically assess intersection and interchange alternatives. Any public involvement as part of the Virginia iCAP process should be conducted consistent with IIM-TMPD-4.0. Additional public engagement requirements for specific project or funding types (e.g., SMART SCALE) should be discussed at the scoping meeting.

### 2.2.2 Stage 1 Sketch and Cost Estimate

**Stage 1 Sketch**

The project team should prepare a Stage 1 sketch for each viable alternative that is screened using VJuST to provide an understanding of the footprint of each alternative and aid in identifying potential right-of-way and utility impacts. At a minimum, Stage 1 sketches should be drawn to scale and illustrated on aerial imagery with the allowed turning movements shown for each approach. Figure 6 presents an example Stage 1 intersection sketch. Figure 6 depicts a quadrant roadway alternative using computer-aided design (CAD) software. Though not required for Stage 1 sketches, CAD graphics provide quality visual representations of alternatives. The conceptual layout includes key components like the footprint of the concept, anticipated right-of-way impacts, and graphics depicting proposed turn configurations.
**Figure 6: Stage 1 Sketch Example (CAD)**

**Stage 1 Cost Category**
VJuST provides a planning-level cost category for each alternative. The Virginia iCAP Tool reports the planning-level cost category value in the Stage 1 Performance Matrix.

**2.2.3 Stage 1 Metric Performance Ranking**
A performance matrix allows a holistic consideration by displaying various metrics in one view; therefore, it is often used during alternatives analyses to determine which intersection alternatives best fulfill the project purpose and need. The Virginia iCAP Tool includes a framework to screen intersection alternatives during Stage 1 of the Virginia iCAP assessment. The matrix, referred to as the Stage 1 Performance Matrix, is used to evaluate each intersection alternative based on four metrics: traffic operations, pedestrian accommodation, safety, and planning-level cost. Guidance on the Stage 1 Performance Matrix, including how each metric score is calculated and how to interpret the results, is provided in Chapter 3. Appendix A includes five Virginia iCAP case studies that provide further examples of the Stage 1 metric performance matrix and guidance for practitioners to interpret the results.

**2.3 Virginia iCAP Assessment Stage 2: Alternatives Assessment**
The goal of the Stage 2 alternatives assessment is to further refine alternatives through detailed analysis.
Figure 7 depicts the Stage 2 procedure and identifies key decisions to be made by the project team at this stage.

During Stage 2, the project team will evaluate the traffic operations and safety performance of each alternative, develop Stage 2 sketches and cost estimates, and rank alternatives to select one preferred alternative to submit to VDOT for review and approval.

The detailed analysis performed during Stage 2 should include refined considerations for how all roadway users will be accommodated by the alternatives assessed. Refer to the following VDOT resources for guidance to appropriately incorporate pedestrian and bicycle accommodations and traffic signal control phasing and timing into the Virginia iCAP alternatives development process:

- IIM-TMPD-1.0 *Implementation of the CTB Policy for Integrating Bicycle and Pedestrian Accommodations*\(^\text{12}\)
- IIM-TE-384.0 *Pedestrian Crossing Accommodations at Unsignalized Locations*\(^\text{13}\)
- IIM-TE-381 *Flashing Yellow Arrow Signal Indication for Permissive Left-Turn Movements*\(^\text{14}\)
- IIM-TE-306.1 *Yellow Change Intervals and Red Clearance Intervals*\(^\text{15}\)
- *Guidance for Determination and Documentation of Left-Turn Phasing Mode, Version 1.0*\(^\text{16}\)

Figure 7: Virginia iCAP Assessment Stage 2 Flowchart

\(^{12}\) [https://www.virginiadot.org/business/resources/IIM/TMPD-1.0-Implementation_of_the_CTB_Policy_for_Integrating_Bicycle_and_Pedestrian_Accommodations.pdf](https://www.virginiadot.org/business/resources/IIM/TMPD-1.0-Implementation_of_the_CTB_Policy_for_Integrating_Bicycle_and_Pedestrian_Accommodations.pdf)

\(^{13}\) [https://www.virginiadot.org/business/resources/IIM/TE-384_Ped_Xing_Accommodations_Usignalized_Locs.pdf](https://www.virginiadot.org/business/resources/IIM/TE-384_Ped_Xing_Accommodations_Usignalized_Locs.pdf)

\(^{14}\) [https://www.virginiadot.org/business/resources/IIM/TE-381_Flashing_Yellow_Arrow.pdf](https://www.virginiadot.org/business/resources/IIM/TE-381_Flashing_Yellow_Arrow.pdf)

\(^{15}\) [https://www.virginiadot.org/business/resources/traffic_engineering/memos/TE-306_1_YellowChange_RedClearance_Intervals.pdf](https://www.virginiadot.org/business/resources/traffic_engineering/memos/TE-306_1_YellowChange_RedClearance_Intervals.pdf)

\(^{16}\) [https://www.virginiadot.org/VDOT/Business/asset_upload_file523_149245.pdf](https://www.virginiadot.org/VDOT/Business/asset_upload_file523_149245.pdf)
STAGE 2: ALTERNATIVES ASSESSMENT

2.1 Additional Data Collection
Input data into the Virginia iCAP Tool Stage 2 Input Worksheet

2.2 Operations and Safety Performance Evaluation
2.2.1 Perform operational analysis using appropriate tool per TOSAM
2.2.2 Input results into the Virginia iCAP Tool Stage 2 Input Worksheet
2.2.3 Review CMF for each potential alternative

2.3 Stage 2 Sketch and Cost
2.3.1 Create Stage 2 refined sketch for each alternative
2.3.2 Complete Stage 2 construction cost estimate for each alternative in VJuST-C

2.4 Metric Performance Ranking
2.4.1 Evaluate and rank alternatives in the Virginia iCAP Tool Stage 2 Performance Matrix

2.5 Document selected alternative and submit to VDOT for approval

Notes:
1 May include coordination with VDOT Highway Safety Improvement Program (HSIP) team

Applicable Reference Document (Manual, IIM, Form)
Applicable Tool

LEGEND
2.3.1 Stage 2 Operations and Safety Performance Evaluation
The traffic operations performance evaluation for Stage 2 should be performed using an analysis tool(s) identified in the VDOT TOSAM and approved by the stakeholder team during the scoping meeting. The selection of the Stage 2 analysis tool(s) will be driven by what MOEs are approved from each analysis tool. MOEs should be selected based on the project purpose and goals, as outlined in the VDOT TOSAM Section 4.1 and agreed upon during the scoping meeting. The VDOT TOSAM Chapter 9 provides further guidance for selecting MOEs and traffic analysis tools during the project scoping phase.

The safety performance evaluation for Stage 2 involves the review and application of appropriate crash modification factors (CMFs) for each alternative. Section 3.5.2 provides additional detail and guidance to conduct the Stage 2 safety performance evaluation.

2.3.2 Stage 2 Sketch and Cost Estimate

Developing a Stage 2 Sketch
The project team should prepare Stage 2 refined sketches for each viable alternative analyzed during Stage 2. Stage 2 refined sketches should be drawn to scale using a CAD software, illustrated on aerial imagery, and depict the allowed turning movements for each approach. In addition, each sketch should include the following information:

- Legend clearly delineating full depth pavement areas, overlay areas, and existing pavement areas
- Transparent shading that clearly depicts colors and/or patterns included in the legend
- Existing property lines and potential right-of-way impacts

Figure 8 presents a Stage 2 refined sketch that depicts turn lane improvements at a signalized intersection. The sketch includes transparent linework and shading shown on a recent aerial. All items that are depicted in the sketch (e.g., proposed mill and overlay, full depth pavement, concrete items) are represented in the legend. In addition, a typical section is provided illustrating travel lane and median widths.
Figure 8: Stage 2 Refined Sketch Example

Developing a Stage 2 Cost Estimate
Following the development of a Stage 2 refined sketch, prepare a cost estimate using VJuST-C. VJuST-C is presented in a similar format as VJuST and includes user instructions within the tool. A planning-level cost estimate should be prepared for each alternative assessed in Stage 2.
2.4 Reporting and Approvals

IIM-TOD-397 outlines reporting and approval requirements for Virginia iCAP assessments. A Virginia iCAP assessment can be part of a variety of project types, but as a minimum for each intersection where a full Virginia iCAP assessment is being completed, the following items must be submitted to the VDOT DTE, or designee, for approval:

- Memo, which documents assessment assumptions and preferred alternative
- Virginia iCAP Applicability Form
- Virginia iCAP Tool and iCAP Tool output
- VJuST output
- Stage 1 sketches
- Stage 2 refined sketch(es) and VJuST-C output
- Traffic analysis tool output(s) from analysis tool(s) selected per the VDOT TOSAM
- Traffic analysis and safety data
- Warrant study if a traffic signal is included within the recommended alternative per IIM-TE-387\(^\text{17}\)

As established in IIM-TOD-397, the VDOT DTE or their designee will be responsible for reviewing Virginia iCAP assessments. Through reviewing a Virginia iCAP assessment, the reviewer will confirm that a Virginia iCAP assessment will be performed for the project (project applicability), evaluate if the project team sufficiently considers how intersection and/or interchange control impacts all users, and confirm that the project team provides proper documentation and relevant justification to support the alternatives assessment. It is best practice for the reviewer to be involved with a Virginia iCAP assessment from start to finish of the project, as continued involvement with the project will aid the reviewer in developing a holistic understanding of the project purpose and need and determine whether concepts were screened appropriately within the Virginia iCAP framework. Appendix B includes a reviewers prompt list to serve as a resource to guide the review of Virginia iCAP assessments.

\(^\text{17}\) [https://www.virginiadot.org/business/resources/IIM/TE-387_Signal_Justification_Reports.pdf](https://www.virginiadot.org/business/resources/IIM/TE-387_Signal_Justification_Reports.pdf)
Chapter 3. Virginia iCAP Tool

The Virginia iCAP Tool aids transportation engineers and planners in conducting a Virginia iCAP assessment. The intent of the tool is to help in the decision-making process of identifying the optimal traffic control type at intersections based on project purpose and need.

The tool is a Microsoft Excel®-based macro workbook that consists of the following worksheets:

- Title Page
- Disclaimer & Acknowledgments
- Instructions
- Applicability Flowchart
- Applicability Form
- General Input Worksheet
- Stage 1 Flowchart
- Stage 1 Input Worksheet
- Stage 1 Performance Matrix
- Stage 2 Flowchart
- Stage 2 Input Worksheet
- Stage 2 Performance Matrix
- iCAP Assessment Output (2 worksheets)

3.1 Instructions

Each worksheet of the Virginia iCAP Tool contains reference links and macros. To enable macros, click the “Enable Content” button that appears within the Excel® message bar as shown in Figure 9.

Figure 9: Virginia iCAP Tool Enable Content Warning

The user should also verify that macros are enabled before using the tool to enable the following features:

- Sheet navigation
- Data import from VJuST and VJuST-C
- Creation of experienced travel time (ETT) spreadsheets during Stage 2

The tool requires several user inputs to complete a Virginia iCAP assessment. Table 2 describes each input type and its corresponding description within the tool. Prior to entering any inputs, the user must read and acknowledge the disclaimer provided on the Disclaimer & Acknowledgments sheet of the Virginia iCAP Tool.

Table 2: Data Field Input Legend

<table>
<thead>
<tr>
<th>Legend</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Required data field – user input</td>
</tr>
<tr>
<td></td>
<td>Data field determined by the Virginia iCAP tool</td>
</tr>
<tr>
<td></td>
<td>Data field not required</td>
</tr>
</tbody>
</table>


3.2 Applicability and General Input Worksheet

3.2.1 Applicability Form
The user should refer to IIM-TOD-397 to determine whether a Virginia iCAP assessment is required based on facility type and the project purpose and need. After reviewing the Virginia iCAP applicability requirements, each proposed location for assessment should be discussed with the VDOT DTE, or designee, to determine the need for a Virginia iCAP assessment. The Applicability Form is required for VDOT-led study or design projects that meet any of the following criteria:

- The project is on the APN
- The project is on a VDOT-maintained facility and signalization is considered

After discussion with the VDOT DTE or their designee, the Virginia iCAP Applicability Form should be submitted to document whether an assessment is required. If the project meets the applicability criteria but is excluded from a Virginia iCAP assessment, document the exclusion in the Applicability Form and provide justification for why the project is excluded.

Since, the Virginia iCAP process is best practice when evaluating intersection control—based on local context and discussions with VDOT DTE/designee and project managers—a Virginia iCAP assessment may be performed even if it is not required by policy.

3.2.2 General Input Worksheet
Once the applicability of the project is determined, the general project information should be collected and documented in the Virginia iCAP Tool General Input Worksheet shown in Figure 10 and Figure 11. The worksheet includes sections for the user to input the project purpose and need and traffic, safety, and multimodal information. These inputs are intended to document the existing conditions at the study intersection.

Figure 10: Virginia iCAP Tool General Input Worksheet

<table>
<thead>
<tr>
<th>Locality/County</th>
<th>Matrix County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>US 404 and Reeves Road</td>
</tr>
<tr>
<td>Is the Intersection/Interchange Located on the APN?</td>
<td>Yes</td>
</tr>
<tr>
<td>Project Type</td>
<td>Traffic Impact Analysis (TIA)</td>
</tr>
<tr>
<td>Project Description</td>
<td>Proposed mixed use development</td>
</tr>
<tr>
<td>Current Year</td>
<td>2022</td>
</tr>
<tr>
<td>Design Year or Future Year</td>
<td>2026</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Traffic and Safety Conditions</th>
<th>Existing Intersection V/C Ratio</th>
<th>0.75</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Future Intersection V/C Ratio</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>PSI Segment Ranking</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>PSI Intersection Ranking</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Multimodal Conditions</th>
<th>VDOT Pedestrian Safety Action Plan (PSAP) Corridor?</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bicycle and/or Pedestrian Generator?</td>
<td>Yes</td>
</tr>
</tbody>
</table>

| Project Purpose and Need | Example analysis of proposed mixed use development. |
Traffic and Safety Conditions: The user can access intersection volume-to-capacity (v/c) ratio and Potential for Safety Improvement (PSI) data using the VDOT Pathways for Planning interactive mapping and data analysis tool. The VDOT Pathways for Planning Tool allows the user to spatially view and query data for the project study area. The PSI Intersections and Segments layers show the VDOT District PSI ranking for given intersections and segments within the study area, as presented in Figure 12.

Multimodal Conditions: The user can access pedestrian data using the VDOT Pedestrian Safety Action Plan (PSAP) interactive mapping and data analysis tool shown in Figure 13. The user should document whether the study intersection is located on a PSAP priority corridor or within a top crash cluster.

As provided in the VDOT Policy for Integrating Bicycle and Pedestrian Accommodations, bicycle and pedestrian generators include employment, education, retail, recreation, and residential centers and public facilities. List applicable bicycle and/or pedestrian generators in the data input field on the Stage 1 Input Worksheet. The State Bicycle Policy Plan and State Pedestrian Policy Plan can be referred to consider bike and pedestrian needs.

---

18 https://vdotp4p.com/
19 https://www.arcgis.com/apps/webappviewer/index.html?id=8c902d598ba84053b1e7c51af332b71
Figure 12: VDOT Pathways for Planning Tool Potential for Safety Improvement (PSI) Layers

Figure 13: VDOT Pedestrian Safety Action Plan (PSAP) Interactive Mapping Tool

- **VTrans Mid-term Needs and Priorities**: VTrans is Virginia’s multimodal transportation plan that is outlined by the Commonwealth Transportation Board (CTB). VTrans needs should be indicated in the Virginia iCAP Tool General Input Worksheet to document multimodal needs corresponding to CTB goals and objectives outlined in VTrans. The user can identify VTrans mid-term needs and priorities using the *VTrans Mid-term Needs and Priorities Map*. The map provides the location, priority, and supporting information for vehicular, transit, bicycle, and pedestrian needs.

Detailed information on the VTrans mid-term needs and the prioritization of each need is provided in the *Policy Guide for the Identification and Prioritization of the VTrans Mid-Term Needs* and the

---


Technical Guide for the Identification and Prioritization of the VTrans Mid-Term Needs. Figure 14 shows the 2019 VTrans mid-term needs and priorities map filtered to the Bicycle Access to Activity Centers (Regional Network) need on US 29 near Charlottesville. The Very High priority along US 29 suggests that future intersection alternatives should consider bicycle accommodations. The presence of a VTrans need of any priority level should warrant the consideration of including improvements or accommodations that address the need.

The user can input the VTrans mid-term need priority for the most recently published VTrans data. If an intersection has multiple priority segments for a given VTrans need within the influence area of the intersection or intersections, input the highest priority present. The user should assume an intersection influence area extends the length of the turn lane storage or at least 250’ upstream from the intersection on each approach. Section 3.3 includes additional guidance to determine Virginia iCAP metric weightings given the presence of VTrans mid-term needs.

Figure 14: VTrans Mid-term Needs and Priorities Bicycle Access Layer (as of June 2023)

3.3 Metric Weighting

Stage 1 and Stage 2 of the Virginia iCAP process consider the priority of the traffic operations, pedestrian, safety, and cost metrics when ranking alternatives. Metric weightings should be based on the project purpose and need and reflect the priority of VTrans needs identified in the corridor.

The user, in coordination with the VDOT DTE or designees and other project stakeholders, should establish the Virginia iCAP metric weightings based on a scale relative to the needs and objectives of the project. The Virginia SMART SCALE\(^2\) funding process provides an example of metric prioritization based on regional needs. In dense metropolitan regions, such as Northern Virginia and Hampton Roads (Category A), priority is assigned to congestion mitigation and land use, while in rural, less developed areas (Category D), priority is assigned to economic development and safety. Although not every SMART SCALE metric is included in the Virginia iCAP Tool, the Virginia SMART SCALE weighting methodology


\(^{26}\) [https://smartscale.org/about/default.asp](https://smartscale.org/about/default.asp)
can be referenced as a regional guide when defining metric weightings; however, local context and the project-specific needs should also be considered during the weighting process.

The user should refer to the data in the General Input Worksheet and the Stage 1 Input Worksheet along with input from project stakeholders to determine priority needs in the corridor when defining metric weightings. **Table 3** provides guidance for determining metric weightings with a non-exhaustive list of relevant data for each metric. For example, the presence of PSI intersections or segments in the project study area should guide the weighting of the safety metric.

Weightings for metrics must be at least one and no greater than three. The goal of a Virginia iCAP assessment is to holistically determine the best intersection alternative satisfying the project purpose and need. Therefore, a minimum weighting of one ensures that all metrics are accounted for in the Virginia iCAP assessment. The maximum weighting of three mitigates the risk of over-prioritizing one metric. Example metric weightings based on the project purpose and need are outlined in the following sections.

**Table 3: Reference Data for Determining Virginia iCAP Metric Weightings**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Relevant Data for Determining Metric Weighting</th>
</tr>
</thead>
</table>
| Traffic Operations | • Existing and future v/c ratios  
                           • Capacity preservation, congestion mitigation, reliability VTrans needs  
                           • Project purpose and need |
| Pedestrian   | • VDOT PSAP priority corridor or crash cluster  
                           • Bicycle and/or pedestrian generator  
                           • Bicycle and pedestrian access, and pedestrian safety improvement VTrans needs  
                           • Number of pedestrian and bicycle crashes  
                           • Existing pedestrian and bicycle accommodations  
                           • Project purpose and need |
| Safety       | • Presence of PSI segments or intersections  
                           • Safety improvement VTrans need  
                           • Fatal and injury crash history  
                           • Project purpose and need |
| Cost         | • Availability of project funding  
                           • Project purpose and need |
**Metric Weighting Example 1: Traffic Operations Priority**

*Project description: an example project is on a congested, regionally significant corridor where future development is planned. There are existing shared-use paths and sidewalks in the study area. The purpose of the project is to relieve existing congestion and provide sufficient capacity, enhanced safety, and access to accommodate anticipated growth.*

*Figure 15* depicts the example metric weighting distribution. Based on the project purpose and objectives, the traffic operations metric is the highest priority. Maintaining pedestrian access and enhancing safety conditions are important to the project, but have lesser priority than improved traffic operations, and higher than the anticipated cost due to the need to accommodate future development in the area. Cost is of lower priority for this project given the regional significance of the project and the potential complexity of improvements. Therefore, the traffic operations metric is given a weighting of three, pedestrian and safety a weighting of two, and cost a weighting of one.

*Figure 15: Traffic Operations Priority Metric Weighting  
*Total Score = 8*

**Metric Weighting Example 2: Safety Priority**

*Project description: an example project is along a median-separated, rural corridor with potential for future development. The study intersection has a notable crash history, especially given the relatively low vehicle-miles traveled through the intersection.*

*Figure 16* depicts the example metric weighting distribution. Based on the project purpose and objectives, safety is of highest priority. Although there is no pressing need for pedestrian access or congestion mitigation, the project team should not overlook the other metrics, as there are future developments planned near the study intersection. Therefore, the team assigns safety a metric weighting of three and the other metrics a weighting of one.

*Figure 16: Safety Priority Metric Weighting  
*Total Score = 6*
3.4 Stage 1: Alternatives Screening

The Stage 1 Alternatives Screening involves a high-level analysis using VJuST. The screenshots from the Virginia iCAP Tool presented in this section include sample project data for educational reference.

3.4.1 Stage 1 Input Worksheet

Virginia iCAP analyses require the collection of traffic operations, traffic safety, and multimodal data for the intersection. The following data should be documented in the Virginia iCAP Tool Stage 1 Input Worksheet shown in Figure 17.

Figure 17: Virginia iCAP Tool Stage 1 Input Worksheet

- **Scenario**: The user should specify the intersection being analyzed. It is recommended that the scenario name indicate the forecast horizon year and peak hour (e.g., 2040 AM Peak Hour). Multiple iterations of the tool may be required to evaluate multiple peak periods, depending on the differences observed in travel patterns between peak periods. The determination of temporal limits should be agreed upon during the scoping meeting.

- **Traffic Data Summary**: The user should import hourly turning movement volumes and truck percentages in each direction from VJuST by pressing the Import VJuST Inputs button and selecting the VJuST file from which volumes will be populated. Future year traffic volumes used in the analysis should be consistent with the horizon year selected during the project scoping stage. If the study intersection is a non-standard configuration, the user should document assumptions defining the direction of each approach since these volumes will be read into subsequent sheets of the Virginia...
iCAP Tool and will impact screening results. The user should input the time period over which pedestrian and bicycle counts were collected (1-hour, 4-hour, daily, etc.) and the volumes along each approach if pedestrian and bicyclist counts are required for the project.

- **Fatal and Injury Crashes**: Vehicular crash data, expressed as the number of fatal and injury crashes, is used to evaluate the safety benefits of potential intersection alternatives during Stage 2: Alternatives Assessment. Within the Crash Data Summary Table, the user should input the number of fatal and injury crashes in the intersection influence area. Virginia crash data is owned and maintained by the Virginia Department of Motor Vehicles (DMV) and can be accessed through VDOT’s Crash Analysis Tool. Refer to the VDOT TOSAM for guidance on safety data.

- **Bicycle and Pedestrian Crashes**: The user should identify if the intersection lies on a VDOT PSAP corridor, as well as input the number of bicycle and pedestrian crashes, if any, within the intersection influence area. The review of PSAP and bicycle and pedestrian crashes during Stage 1 is necessary to determine if potential alternatives should address multimodal crashes, and may guide the weighting of the pedestrian metric in the Stage 1 Performance Matrix, described in Section 3.4.2.

- **Existing Multimodal Accommodations**: The user should identify and document existing multimodal accommodations near the study intersection such as existing sidewalks, pedestrian signals and pushbuttons, bikeways, shared-use paths and trails, bus routes, bus stops and transit shelters, and passenger rail stations. The presence of multimodal accommodations may influence the concept screening process and prioritization of alternatives. The user should reference relevant planning documents, including the governing jurisdiction comprehensive plan, bicycle and pedestrian master plan, and/or transit plans to further understand existing and planned multimodal accommodations at the study intersection. Additional bicycle and pedestrian resources include the VDOT Statewide Bicycle and Pedestrian Program Website and VTrans.

---

27 Refer to the Highway Safety Manual (HSM) Part C for guidance on defining crash influence areas.
29 [https://vdot.maps.arcgis.com/apps/webappviewer/index.html?id=8c902d598ba84053b1e7c51afc3332b71](https://vdot.maps.arcgis.com/apps/webappviewer/index.html?id=8c902d598ba84053b1e7c51afc3332b71)
30 [https://www.virginiadot.org/programs/bikeped/default.asp](https://www.virginiadot.org/programs/bikeped/default.asp)
3.4.2 Stage 1 Performance Matrix

The Stage 1 Performance Matrix, shown in Figure 18 and Figure 19, is a consistent framework to screen intersection alternatives based on four metrics: traffic operations, pedestrian, safety, and Stage 1 cost. The metrics are expressed as the following screening-level MOEs reported from VJuST.

- **Traffic Operations**: maximum v/c ratio
- **Pedestrian**: accommodation compared to a conventional intersection
- **Safety**: weighted total conflict points
- **Stage 1 Cost**: planning-level cost category

Each metric has a unique weighting and methodology to calculate a Stage 1 metric score based on the respective MOEs.

Note: the Virginia iCAP Tool is a planning-level alternatives screening tool. Therefore, the high-level assumptions built into it may not represent all design possibilities, potential benefits or drawbacks, or refined cost estimates that accurately capture project-specific outcomes. Hence, it is imperative to apply engineering judgment at critical junctures of the Virginia iCAP process, e.g., during alternative selection in Stage 1 or Stage 2, and document key assumptions made, which will add context and support to the decisions made throughout the Virginia iCAP process.

**Figure 18: Virginia iCAP Tool Stage 1 Performance Matrix**

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Traffic Operations</th>
<th>Pedestrian</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VJuST Maximum V/C Ratio</td>
<td>Traffic Operations Metric MOE Score</td>
</tr>
<tr>
<td>Existing</td>
<td>Conventional</td>
<td>1.00</td>
</tr>
<tr>
<td>Alternative 1</td>
<td>Bowtie NB-SB</td>
<td>0.90</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>Conventional</td>
<td>0.93</td>
</tr>
<tr>
<td>Alternative 3</td>
<td>Quadrant Roadway S-W</td>
<td>0.86</td>
</tr>
<tr>
<td>Alternative 4</td>
<td>Restricted Crossing U-Turn EB-WB</td>
<td>0.92</td>
</tr>
</tbody>
</table>

Traffic Operations Weight: 2

Pedestrian Weight: 2
**Entering Data into the Stage 1 Performance Matrix**

There are two methods to enter data into the Stage 1 Performance Matrix:

- VJuST Import Macro (Preferred)
- Manual Entry

Using the VJuST Import Macro method is preferred because doing so will maintain consistency between the Virginia iCAP Tool and VJuST screening. When importing results from VJuST, select “Import VJuST Results”. The macro imports traffic operations, pedestrian, safety, and cost results from the VJuST Results Worksheet. If an alternative version of the existing configuration is evaluated in the future scenario (e.g., additional turn lanes at a conventional intersection), two VJuST files should be created to allow for the input of both the existing and potential future configurations:

- VJuST File 1: Existing or Base Scenario Condition
- VJuST File 2: Future Scenario Alternatives, including modified version of the existing configuration

---

### Alternatives

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>VJuST Weighted Total Conflict Points</th>
<th>Safety Metric MOE Score</th>
<th>VJuST Planning Level Cost Category</th>
<th>Stage 1 Cost Metric MOE Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Conventional</td>
<td>48</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Alternative 1 Bowtie NB-SB</td>
<td>24</td>
<td>0.9</td>
<td>$$$</td>
<td>0.3</td>
</tr>
<tr>
<td>Alternative 2 Conventional</td>
<td>48</td>
<td>0.0</td>
<td>$</td>
<td>1.0</td>
</tr>
<tr>
<td>Alternative 3 Quadrant Roadway S-W</td>
<td>40</td>
<td>0.3</td>
<td>$$$</td>
<td>0.3</td>
</tr>
<tr>
<td>Alternative 4 Restricted Crossing U-Turn EB-WB</td>
<td>20</td>
<td>1.0</td>
<td>$</td>
<td>0.5</td>
</tr>
</tbody>
</table>

### Alternatives for Stage 2 Analysis

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Total Stage 1 Score</th>
<th>Selected Alternative for Stage 2 Analysis? (Maximum 5)</th>
<th>Justification*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Conventional</td>
<td>6.4 out of 8</td>
<td>Yes</td>
<td>Significant safety and traffic operations improvement</td>
</tr>
<tr>
<td>Alternative 1 Bowtie NB-SB</td>
<td>3 out of 8</td>
<td>No</td>
<td>No anticipated safety improvement</td>
</tr>
<tr>
<td>Alternative 3 Quadrant Roadway S-W</td>
<td>4.2 out of 8</td>
<td>No</td>
<td>Additional access to US 404 causes concerns with capacity preservation need</td>
</tr>
<tr>
<td>Alternative 4 Restricted Crossing U-Turn EB-WB</td>
<td>5.7 out of 8</td>
<td>Yes</td>
<td>Significant safety and traffic operations improvement</td>
</tr>
</tbody>
</table>

*Justification for each alternative is required*
In the case where an alternative version of the existing configuration is evaluated in the future scenario, the user should select the existing configuration by importing the existing or base scenario condition VJuST file, then follow the selections shown in Figure 20. Then, the user will import the future scenario alternatives VJuST file and select “None of the Above” when prompted to “Select File Containing Existing Configuration” as shown in Figure 21.

Figure 20: Virginia iCAP Tool VJuST Results Import – Existing or Base Condition Configuration

Figure 21: Virginia iCAP Tool VJuST Results Import - Alternative Configurations
The user cannot copy sheets within VJuST to account for multiple alternatives with similar intersection or interchange designs, so if multiple alternatives are considered with similar designs (e.g., two conventional alternatives), the user must create a new VJuST file for each alternative. Only in rare instances when VJuST is incompatible with the existing intersection configuration should analysis in VJuST be omitted from Stage 1 of the Virginia iCAP assessment. One example of where VJuST is incompatible is if the base condition configuration is a five-legged intersection. Refer to Section 4.4 for additional guidance for analyzing five-legged intersections.

3.4.3 Stage 1 Metric Methodology
Stage 1 metrics report the performance of each alternative derived from an MOE output from VJuST. The score for each metric is depicted in Figure 22 as the product of the priority, expressed as the metric weighting, and performance, expressed as the metric MOE score.

The following subsections describe how the Virginia iCAP Tool calculates each Stage 1 metric MOE score. Appendix C summarizes the MOE definition, source, and possible score for each Stage 1 metric.

Figure 22: Stage 1 Scoring Methodology

**Traffic Operations Metric**
To calculate the Stage 1 Traffic Operations Metric MOE Score, the difference in v/c ratio between each alternative and the base condition is calculated. The metric MOE score is then based on the benefit of each alternative compared to the base condition—in this case the reduction in the v/c ratio. The alternative with the highest reduction in v/c ratio is assigned a score of one. All other alternatives receive a score between zero and one as a percentage of the highest reduction in v/c ratio, as shown in Equation 1. If an alternative does not reduce the v/c ratio compared to the base condition, the alternative receives a score of zero.
Equation 1: Stage 1 Traffic Operations Metric MOE Score Calculation

\[ \text{Score} = \frac{\text{Base Condition } \frac{V}{C} - \text{Alternative } \frac{V}{C}}{\text{Maximum} \left[ \text{Base Condition } \frac{V}{C} - \text{Alternative } \frac{V}{C} \right]} \]

OR

\[ \text{Score} = 0 \text{ when } \text{Base Condition } \frac{V}{C} - \text{Alternative } \frac{V}{C} \leq 0 \]

Figure 23 shows an example set of alternatives and illustrates the methodology for Traffic Operations Metric MOE scoring. In this example, there is one alternative receiving a score of zero with a v/c ratio worse than the base condition configuration. The two alternatives with the highest v/c ratio improvement receive a score of one. All alternatives that show a v/c improvement compared to the base condition receive a score between zero and one.

Figure 23: Virginia iCAP Tool Example Traffic Operations Metric MOE Scoring

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>VJuST Maximum V/C Ratio</th>
<th>V/C Ratio Improvement</th>
<th>Traffic Operations Metric Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>Conventional</td>
<td>1.27</td>
<td>--</td>
</tr>
<tr>
<td>Alternative 1</td>
<td>Bowtie EB-WB</td>
<td>1.28</td>
<td>-0.01</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>Full Displaced Left Turn</td>
<td>0.99</td>
<td>0.28</td>
</tr>
<tr>
<td>Alternative 3</td>
<td>Median U-Turn NB-SB</td>
<td>1.10</td>
<td>0.17</td>
</tr>
<tr>
<td>Alternative 4</td>
<td>Partial Displaced Left Turn NB-SB</td>
<td>1.03</td>
<td>0.24</td>
</tr>
<tr>
<td>Alternative 5</td>
<td>Partial Median U-Turn NB-SB</td>
<td>1.08</td>
<td>0.19</td>
</tr>
<tr>
<td>Alternative 6</td>
<td>Quadrant Roadway N-E</td>
<td>1.23</td>
<td>0.04</td>
</tr>
<tr>
<td>Alternative 7</td>
<td>Quadrant Roadway N-W</td>
<td>1.07</td>
<td>0.20</td>
</tr>
<tr>
<td>Alternative 8</td>
<td>Restricted Crossing U-Turn NB-SB</td>
<td>0.99</td>
<td>0.23</td>
</tr>
</tbody>
</table>

**Pedestrian Metric**

The Pedestrian Metric MOE Score is assigned based on the pedestrian accommodation of each alternative. VJuST defines the pedestrian metric as “the potential of an intersection or interchange configuration to accommodate pedestrians based on safety, wayfinding, and delay.” The pedestrian accommodation is qualitatively described as better, similar, or worse when compared to a conventional intersection or traditional diamond interchange. Table 4 summarizes the Stage 1 Pedestrian Metric MOE scores for pedestrian accommodations that are better, similar, or worse than a conventional intersection or traditional diamond interchange.
Table 4: Virginia iCAP Tool Stage 1 Pedestrian Metric MOE Scoring Definition

<table>
<thead>
<tr>
<th>Effect</th>
<th>Description</th>
<th>Pedestrian Metric MOE Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>Accommodation is better than a conventional intersection or traditional diamond interchange</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>Accommodation is similar to a conventional intersection or traditional diamond interchange</td>
<td>0.5</td>
</tr>
<tr>
<td>-</td>
<td>Accommodation is worse than a conventional intersection or traditional diamond interchange</td>
<td>0</td>
</tr>
</tbody>
</table>

**Safety Metric**
To calculate the Stage 1 Safety Metric MOE Score, the weighted total conflict points of each alternative is compared to the other alternatives. VJuST determines the weighted total conflict points of each intersection or interchange configuration as the sum of the merging, diverging, and twice the number of crossing conflicts. Note that VJuST does not automatically calculate the weighted total conflict points for three-legged intersections. To compare three-legged intersection configurations, conflicts corresponding with the fourth leg of the intersection must be removed. The methodology for determining the weighted number of conflict points is outlined in the VJuST Safety Information worksheet.

The alternative with the fewest conflict points, which represents the alternative with the highest reduction in conflict points and greatest potential safety benefit, is assigned a score of 1. Consistent with the Traffic Operations Metric MOE Score methodology, the Virginia iCAP tool calculates the Safety Metric MOE Score as a percentage of the highest reduction in conflict points. If an alternative does not reduce the number of conflict points, the alternative receives a score of zero, as shown in Equation 2.

**Equation 2: Stage 1 Safety Metric Score Calculation**

\[
Score = \frac{CP_{Base \ Condition} - CP_{Alternative}}{\text{Maximum}[CP_{Base \ Condition} - CP_{Alternative}]}
\]

OR

Score = 0 when \( CP_{Base \ Condition} - CP_{Alternative} \leq 0 \)

Where: \( CP = \text{Conflict Points} \)

**Cost Metric**
The Virginia iCAP Tool Stage 1 Cost Metric MOE Score is reported as the VJuST planning-level cost category, which ranges from the cost category 1 ($) to cost category 5 ($$$$$), where $ represents the lowest-cost alternatives and $$$$$ represents the highest-cost alternatives.

The alternative with the lowest cost category is assigned a score of 1. All other alternatives receive a score between 0.2 and 1 as a quotient of the lowest cost category divided by the alternative cost category, shown in Equation 3.

**Equation 3: Stage 1 Cost Metric MOE Score Calculation**

\[
Score = \frac{\text{Minimum}[\text{Alternative Cost Category}]}{\text{Alternative Cost Category}}
\]
3.4.4 Stage 1 Alternative Selection and Alternative Justification Guidance

The Virginia iCAP Tool calculates a total Stage 1 score for each alternative after the user determines each metric weighting and inputs the required data into the Stage 1 Performance Matrix. The total Stage 1 score is the sum of each metric score. The score is displayed out of the total possible score, which is equal to the sum of the traffic operations, pedestrian, safety, and cost metric weightings. The color scale of each total score is based on the distribution of scores across alternatives.

Figure 24 provides an example for a total possible score of ten based on the metric weighting of:

- Traffic Operations = 2
- Pedestrian = 2
- Safety = 3
- Cost = 3

The total score for each alternative is provided and formatted to show the differentiation between high- and low-scoring alternatives.

Although the total score and color scale is useful for identifying the highest-ranking alternatives, the user should not select alternatives for further analysis in Stage 2 solely on the total Stage 1 score. The Virginia iCAP process provides a consistent decision-making framework for screening intersection alternatives; however, the Stage 1 screening procedure is limited in the level of detail it captures for each intersection or interchange configuration. Therefore, the project team should consider the feasibility of the alternative aside from what is captured in the total Stage 1 score. Some questions to consider are:

- Does this configuration appropriately serve travel patterns?
- Would rerouting turning movements unacceptably impact operations at adjacent intersections?
- Is the configuration compatible with adjacent intersections and/or land use?
- Is there local knowledge that should be considered in the decision-making process?

The user should provide justification for why an alternative was or was not selected to advance to Stage 2 for detailed analysis. Examples of justification for selecting an alternative may include:

- The alternative is compatible with roadway geometry and spacing
- The alternative improves operations or safety
- The alternative maintains or enhances pedestrian access

Examples of justification for not selecting an alternative for further analysis may include:

- The alternative does not improve or worsens safety
- The alternative degrades traffic operations
- The alternative requires significant right-of-way takes
- The alternative restricts bicycle or pedestrian access
- The alternative precludes improvements to adjacent intersections
Figure 24: Virginia iCAP Tool Example Total Possible Score and Stage 1 Score Example

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Traffic Operations</th>
<th>Pedestrian</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VJuST Maximum V/C Ratio</td>
<td>Traffic Operations Metric MOE Score</td>
</tr>
<tr>
<td>Existing</td>
<td>Conventional</td>
<td>1.00</td>
</tr>
<tr>
<td>Alternative 1</td>
<td>Bowtie NB-SB</td>
<td>0.90</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>Conventional</td>
<td>0.93</td>
</tr>
<tr>
<td>Alternative 3</td>
<td>Quadrant Roadway S-W</td>
<td>0.86</td>
</tr>
<tr>
<td>Alternative 4</td>
<td>Restricted Crossing U-Turn EB-WB</td>
<td>0.92</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Safety</th>
<th>Stage 1 Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VJuST Weighted Total Conflict Points</td>
<td>Safety Metric MOE Score</td>
</tr>
<tr>
<td>Existing</td>
<td>Conventional</td>
<td>48</td>
</tr>
<tr>
<td>Alternative 1</td>
<td>Bowtie NB-SB</td>
<td>24</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>Conventional</td>
<td>48</td>
</tr>
<tr>
<td>Alternative 3</td>
<td>Quadrant Roadway S-W</td>
<td>40</td>
</tr>
<tr>
<td>Alternative 4</td>
<td>Restricted Crossing U-Turn EB-WB</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Total Possible Score</th>
<th>Alternatives for Stage 2 Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Stage 1 Score</td>
<td>Selected Alternative for Stage 2 Analysis? (Maximum 5)</td>
</tr>
<tr>
<td>Existing</td>
<td>Conventional</td>
<td>7 out of 10</td>
</tr>
<tr>
<td>Alternative 1</td>
<td>Bowtie NB-SB</td>
<td>7 out of 10</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>Conventional</td>
<td>5 out of 10</td>
</tr>
<tr>
<td>Alternative 3</td>
<td>Quadrant Roadway S-W</td>
<td>4.8 out of 10</td>
</tr>
<tr>
<td>Alternative 4</td>
<td>Restricted Crossing U-Turn EB-WB</td>
<td>6.7 out of 10</td>
</tr>
</tbody>
</table>
The Virginia iCAP tool allows for up to five alternatives to be selected for Stage 2 evaluation. The alternatives selected for Stage 2 evaluation can be exported to the Stage 2 Input Worksheet using the Export Selected Alternatives to Stage 2 button, shown in Figure 25.

Figure 25: Export Selected Alternatives to Stage 2 Button

<table>
<thead>
<tr>
<th>Total Possible Score</th>
<th>Alternatives for Stage 2 Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Stage 1 Score</th>
<th>Selected Alternative for Stage 2 Analysis?</th>
<th>Justification*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Maximum 5)</td>
<td></td>
</tr>
<tr>
<td>6.4 out of 8</td>
<td>Yes</td>
<td>Significant safety and traffic operations improvement</td>
</tr>
</tbody>
</table>

Total score is the sum of each metric score multiplied by the metric weighting. *Justification for each alternative is required

Total Score Equation

\[
= \sum_{Stage\ 1\ Metric} (Metric\ MOE\ Score \times Metric\ Weighting)
\]
3.5 Stage 2: Alternatives Assessment

The Stage 2 Alternatives Assessment involves a detailed traffic and safety analysis using appropriate tools from the VDOT TOSAM and approved during the scoping meeting. The screenshots from the Virginia iCAP Tool presented in this section include sample project data for educational reference.

3.5.1 Stage 2 Input Worksheet

The following data should be documented in the Virginia iCAP Tool Stage 2 Input Worksheet as depicted in Figure 26 and Figure 27. For demonstration purposes, only the eastbound approach has been included in these screenshots.

- **Alternatives, MOEs, and Critical Approaches**: The user can import the list of selected alternatives from Stage 1 using the Import Selected Alternatives from Stage 1 button. Then, at the top of the worksheet, the user will select the MOEs to be reported using the dropdown menu. The user must select a combination of v/c, queue-, or delay-related MOEs. Two queue- or two delay-related MOEs cannot be selected. Next, the user should define the critical approach or approaches of the intersection. The critical approach represents a portion of the roadway network that is of decisive importance to the recommendations resulting from traffic operations analysis. The user may consider factors such as volume, delay, or operational concerns when defining critical approaches and should provide justification using the dropdown menu under Justification. Approaches with “Is this a Critical Approach?” set to “Yes” will require the user to input results from the Stage 2 analysis.

- **Traffic Analysis Results**: Once the user selects MOEs and performs Stage 2 analysis using the appropriate tools, the user will report results in the Virginia iCAP Stage 2 Input Worksheet. The Virginia iCAP Tool is compatible with the following traffic analysis MOEs adopted from the VDOT TOSAM:
  - 95th percentile queue length
  - Control delay
  - Experienced travel time (ETT)
  - Maximum queue length
  - Microsimulation delay
  - V/C ratio

The user should input MOE results for the base condition (existing) intersection configuration and each alternative. Cells shaded grey denote that the MOE is not a required input because either the approach is not critical or the MOE is not an applicable intersection MOE. The Virginia iCAP Tool calculates the percent difference between the delay and intersection v/c ratio MOEs reported for the base condition configuration and each alternative configuration. The following sections provide specific guidance for reporting the results of each MOE.
### Figure 26: Virginia iCAP Tool Stage 2 Traffic Operations Input Worksheet

<table>
<thead>
<tr>
<th>Measure of Effectiveness</th>
<th>Control Delay</th>
<th>95th Percentile Queue Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approach</td>
<td>Volume</td>
<td>Is this a Critical Approach?</td>
</tr>
<tr>
<td>Eastbound</td>
<td>1095</td>
<td>Yes</td>
</tr>
<tr>
<td>Westbound</td>
<td>2505</td>
<td>Yes</td>
</tr>
<tr>
<td>Northbound</td>
<td>536</td>
<td>Yes</td>
</tr>
<tr>
<td>Southbound</td>
<td>185</td>
<td>No</td>
</tr>
</tbody>
</table>

#### Control Delay MOE Results

*Input flow rates, delay results, and intersection/interchange geometry into the ETT worksheet for this alternative*

<table>
<thead>
<tr>
<th>Approach</th>
<th>Input MOE</th>
<th>Eastbound</th>
<th>% Difference from Base Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base Condition</td>
<td>Conventional</td>
<td>Control Delay</td>
<td>39.0</td>
</tr>
<tr>
<td>Alternative 1</td>
<td>Bowtie NB-SB</td>
<td>Experienced Travel Time (ETT)*</td>
<td>37.7</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>Restricted Crossing U-Turn EB-WB</td>
<td>Experienced Travel Time (ETT)*</td>
<td>26.8</td>
</tr>
</tbody>
</table>

#### Intersection

*Input flow rates, delay results, and intersection/interchange geometry into the ETT worksheet for this alternative*

<table>
<thead>
<tr>
<th>Approach</th>
<th>Input MOE</th>
<th>Intersection</th>
<th>% Difference from Base Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base Condition</td>
<td>Conventional</td>
<td>Control Delay</td>
<td>114.5</td>
</tr>
<tr>
<td>Alternative 1</td>
<td>Bowtie NB-SB</td>
<td>Experienced Travel Time (ETT)*</td>
<td>48.0</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>Restricted Crossing U-Turn EB-WB</td>
<td>Experienced Travel Time (ETT)*</td>
<td>100.7</td>
</tr>
</tbody>
</table>
Figure 27: Virginia iCAP Tool Stage 2 Traffic Operations Input Worksheet - Continued

<table>
<thead>
<tr>
<th>95th Percentile Queue Length MOE Results</th>
<th>Input MOE</th>
<th>Eastbound</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. of Approaches with Queues Accommodated</td>
<td>Total No. of Eastbound Approaches</td>
</tr>
<tr>
<td>Base Condition</td>
<td>Conventional</td>
<td>95th Percentile Queue Length</td>
<td>1</td>
</tr>
<tr>
<td>Alternative 1</td>
<td>Bowtie NB-SB</td>
<td>95th Percentile Queue Length</td>
<td>1</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>Restricted Crossing U-Turn EB-WB</td>
<td>95th Percentile Queue Length</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CONTROL DELAY AND MICROSIMULATION DELAY
The user will input the approach delay for each critical approach.

EXPERIENCED TRAVEL TIME (ETT)
Experienced travel time (ETT) is an MOE only considered for innovative intersections that require the rerouting of turning movements and is not directly selected by the user in the Stage 2 Input Worksheet. The Virginia iCAP Tool will identify whether control delay or microsimulation delay should be reported as experienced travel time for a given alternative. The ETT for an innovative intersection alternative can be determined using a control delay or microsimulation delay output from a traffic analysis tool and by calculating the extra distance travel time needed for rerouting to complete a turn. If the user analyzes an innovative intersection alternative that reroutes vehicles in Stage 2, the Virginia iCAP Tool will automatically populate an ETT calculation sheet as shown in Figure 28, an example ETT calculation sheet for a northwest quadrant roadway intersection alternative.

For each ETT spreadsheet, the user must input four sets of values: the flow rate for each movement in the no-build configuration, the control delays for each lane group reported at each intersection for the alternative configuration, the distances between each intersection, and the speed limit on each roadway. These values should be consistent with the inputs and outputs from the traffic operations analysis tool used for the Stage 2 analysis. If the user imported VJuST results into the Stage 1 Performance Matrix and uses the Export Selected Alternatives to Stage 2 button, the Virginia iCAP Tool will automatically populate the no-build flow rate for each movement in each ETT spreadsheet.

The ETT spreadsheets calculate and report ETT (seconds per vehicle) values for each approach, which are automatically populated in the Stage 2 Input Worksheet for the corresponding alternative.
Figure 28: Virginia iCAP Tool Quadrant Intersection ETT Sheet

Northwest Quadrant Roadway

<table>
<thead>
<tr>
<th>Original O-D</th>
<th>No-Build Flow rate (veh/hr)</th>
<th>New O-D Movements</th>
<th>Control delay (s/veh)</th>
<th>EDTT (s/veh)</th>
<th>ETT (s/veh)</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>EBL</td>
<td>123</td>
<td>EBL (2) + EBL (1)</td>
<td>111.3</td>
<td>8.1</td>
<td>119.4</td>
<td>F</td>
</tr>
<tr>
<td>EBT</td>
<td>218</td>
<td>EBT (2) + EBT (0)</td>
<td>66.5</td>
<td>-</td>
<td>66.5</td>
<td>E</td>
</tr>
<tr>
<td>EBR</td>
<td>345</td>
<td>EBT (2) + EBR (0)</td>
<td>17.2</td>
<td>-</td>
<td>17.2</td>
<td>B</td>
</tr>
<tr>
<td>WBL</td>
<td>166</td>
<td>WBT (0) + WBR (2) + EBR (1) + SBT (0)</td>
<td>131.8</td>
<td>62.4</td>
<td>194.2</td>
<td>F</td>
</tr>
<tr>
<td>WBT</td>
<td>406</td>
<td>WBT (0) + WBT (2)</td>
<td>82.3</td>
<td>-</td>
<td>82.3</td>
<td>F</td>
</tr>
<tr>
<td>WBR</td>
<td>226</td>
<td>WBR (0) + NBR (1)</td>
<td>59.0</td>
<td>-</td>
<td>59.0</td>
<td>E</td>
</tr>
<tr>
<td>NBL</td>
<td>420</td>
<td>NBT (0) + NBL (1) + SBR (2)</td>
<td>100.6</td>
<td>36.9</td>
<td>137.5</td>
<td>F</td>
</tr>
<tr>
<td>NBT</td>
<td>1872</td>
<td>NBT (0) + NBT (1)</td>
<td>30.5</td>
<td>-</td>
<td>30.5</td>
<td>C</td>
</tr>
<tr>
<td>NBR</td>
<td>120</td>
<td>NBR (0)</td>
<td>7.3</td>
<td>-</td>
<td>7.3</td>
<td>A</td>
</tr>
<tr>
<td>SBL</td>
<td>60</td>
<td>SBR (1) + SBL (2) + EBT (0)</td>
<td>108.0</td>
<td>36.9</td>
<td>144.9</td>
<td>F</td>
</tr>
<tr>
<td>SBT</td>
<td>2121</td>
<td>SBT (1) + SBT (0)</td>
<td>33.1</td>
<td>-</td>
<td>33.1</td>
<td>C</td>
</tr>
<tr>
<td>SBR</td>
<td>112</td>
<td>SBR (0)</td>
<td>0.5</td>
<td>-</td>
<td>0.5</td>
<td>A</td>
</tr>
</tbody>
</table>

*Assumed U-turns would dissipate throughout the network and did not include them in volume rerouting

Northwest Quadrant Geometry

- Distance to/from northern crossover (ft): 1032
- Distance to/from western crossover (ft): 1164
- Distance along quadrant connector (ft): 1556
- Major street free-flow speed west of intersection (mi/hr): 55
- Connector Speed (mi/hr): 30

Northwest Quadrant Control Delay

<table>
<thead>
<tr>
<th>Movement</th>
<th>Delay</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>EBT (0)</td>
<td>49.6</td>
<td>Main Intersection (0)</td>
</tr>
<tr>
<td>EBR (0)</td>
<td>0.3</td>
<td>Main Intersection (0)</td>
</tr>
<tr>
<td>WBT (0)</td>
<td>61.4</td>
<td>Main Intersection (0)</td>
</tr>
<tr>
<td>WBR (0)</td>
<td>57.5</td>
<td>Main Intersection (0)</td>
</tr>
<tr>
<td>NBR (0)</td>
<td>7.3</td>
<td>Main Intersection (0)</td>
</tr>
<tr>
<td>NBT (0)</td>
<td>29.0</td>
<td>Main Intersection (0)</td>
</tr>
<tr>
<td>SBR (0)</td>
<td>0.5</td>
<td>Main Intersection (0)</td>
</tr>
<tr>
<td>EBT (0)</td>
<td>10.9</td>
<td>Main Intersection (0)</td>
</tr>
<tr>
<td>EBL (1)</td>
<td>75.1</td>
<td>Northern Intersection (1)</td>
</tr>
<tr>
<td>EBR (1)</td>
<td>38.6</td>
<td>Northern Intersection (1)</td>
</tr>
<tr>
<td>NBL (1)</td>
<td>50.3</td>
<td>Northern Intersection (1)</td>
</tr>
<tr>
<td>NBT (1)</td>
<td>1.5</td>
<td>Northern Intersection (1)</td>
</tr>
<tr>
<td>SBT (1)</td>
<td>22.2</td>
<td>Northern Intersection (1)</td>
</tr>
<tr>
<td>SBR (1)</td>
<td>13.2</td>
<td>Northern Intersection (1)</td>
</tr>
<tr>
<td>EBL (2)</td>
<td>36.2</td>
<td>Western Intersection (2)</td>
</tr>
<tr>
<td>EBT (2)</td>
<td>16.9</td>
<td>Western Intersection (2)</td>
</tr>
<tr>
<td>WBR (2)</td>
<td>20.9</td>
<td>Western Intersection (2)</td>
</tr>
<tr>
<td>SBL (2)</td>
<td>45.2</td>
<td>Western Intersection (2)</td>
</tr>
<tr>
<td>SBR (2)</td>
<td>21.3</td>
<td>Western Intersection (2)</td>
</tr>
</tbody>
</table>
V/C Ratio
The user will input the intersection v/c ratio for each alternative as reported from the traffic analysis tool. If an alternative has multiple intersections, such as a Quadrant Roadway, the user should report the intersection v/c ratio for each node, the Total Intersection V/C Ratio value is the average intersection v/c ratio weighted by entering volume. The Virginia iCAP Tool automatically inputs the entering volume at each intersection referenced from VJuST.

There are several exceptions to consider:
- If the alternative configuration geometry has changed since the Stage 1 VJuST screening, the user should confirm the accuracy of the entering volumes.
- If the alternative has a custom configuration not compatible with VJuST, the user should manually input the intersection v/c and entering volumes (in units of passenger cars per hour) for each intersection.
- For diverging diamond interchange (DDI) alternatives, the user should report the intersection v/c ratios and entering volumes for the nodes with the five highest v/c ratios.

95th Percentile and Maximum Queue Length
The Stage 2 Input Worksheet provides a framework to qualitatively analyze queue length MOEs for each alternative. Using the queue length results from the traffic analysis tool, the user will first determine whether queues are accommodated at each approach of an alternative. Queues are considered to be accommodated on an approach if the queues do not exceed turn lane storage, block adjacent lanes, or block upstream intersections. For alternatives with multiple intersections, the user should assess whether queues are accommodated for both the primary and secondary intersection(s). For the example of an east-west Restricted crossing U-turn (RCUT) configuration, the user would determine whether queues are accommodated on each of the three eastbound and westbound approaches and the northbound and southbound approaches. The user should then input the number of approaches with queues accommodated and the total number of approaches for a given direction. The Virginia iCAP Tool includes several innovative intersection and interchange configurations with multiple intersections. Refer to Table 5 and Table 6 for the standard number of approaches to assess for such configurations.

If queues are not accommodated on all approaches of a direction, the user should determine whether the queues are acceptable and provide justification. Queues are considered acceptable if all or most queues are accommodated within available turn lane storage and do not impact operations at upstream intersections. The user can also consider queues acceptable if the alternative queues are better than the base condition or are acceptable given physical constraints. Queues are not considered acceptable if they negatively impact operations of upstream intersections. Finally, the user should determine whether the queues are acceptable for the overall alternative and provide justification.

Table 5: Standard Number of Approaches for Interchange Configurations with Multiple Intersections

<table>
<thead>
<tr>
<th>Innovative Interchange Configuration</th>
<th>Eastbound Approaches</th>
<th>Westbound Approaches</th>
<th>Northbound Approaches</th>
<th>Southbound Approaches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contraflow left*</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Displaced left Turn*</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Diverging diamond*</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Double roundabout*</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Michigan urban diamond</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Partial cloverleaf</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Traditional diamond (signalized)*</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Traditional diamond (stop-controlled)*</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

*Assumes east-west arterial
### Table 6: Standard Number of Approaches for Innovative Intersections with Multiple Intersections

<table>
<thead>
<tr>
<th>Innovative Intersection Configuration</th>
<th>Eastbound Approaches</th>
<th>Westbound Approaches</th>
<th>Northbound Approaches</th>
<th>Southbound Approaches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowtie EB-WB</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bowtie NB-SB</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Full displaced left turn</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Median U-turn EB-WB</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Median U-turn NB-SB</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Partial displaced left turn EB-WB</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Partial displaced left turn NB-SB</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Partial median U-turn EB-WB</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Partial median U-turn NB-SB</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Quadrant roadway N-E</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Quadrant roadway N-W</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Quadrant roadway S-E</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Quadrant roadway S-W</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Restricted crossing U-turn EB-WB</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Restricted crossing U-turn NB-SB</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Single loop^</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Split intersection†</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

^Assumes connector road in southwest quadrant
†Assumes east-west roadway is split

### 3.5.2 Stage 2 Performance Matrix

The Stage 2 Performance Matrix, shown in Figure 29, provides the user with a framework to perform a more detailed alternatives assessment based on four metrics: Traffic Operations, Pedestrian, Safety, and Stage 2 Cost. Stage 2 MOEs report the performance of an alternative for a given metric. The score for each metric is the product of the metric MOE score (performance) and metric weighting (priority). The Virginia iCAP Tool automatically carries over the metric weightings defined in the General Input Worksheet into the Stage 2 Performance Matrix.

As noted in Section 3.4.2, high-level assumptions built into the Virginia iCAP Tool may not be representative of all design possibilities, potential benefits or drawbacks, or refined cost estimates that accurately capture project-specific outcomes. It is imperative to apply engineering judgment at critical junctures of the Virginia iCAP process and document key assumptions made that add context to support decisions made throughout the Virginia iCAP process.
### Figure 29: Virginia iCAP Tool Stage 2 Performance Matrix

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Traffic Operations Weight</th>
<th>Control Delay</th>
<th>95th Percentile Queue Length</th>
<th>Pedestrian Weight</th>
<th>Safety Weight</th>
<th>Stage 2 Cost Weight</th>
<th>Stage 2 Total Score</th>
<th>Preferred Alternative Selection for Submission to VDOT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metric Weighting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Based on Purpose and Need)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Alternatives</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternative 1: Bowtie NB-SB</td>
<td>42.8</td>
<td>1.0</td>
<td>Yes</td>
<td>3.0</td>
<td>1.0</td>
<td>$8,400,000</td>
<td>7.5 out of 8</td>
<td>Significant operational improvement and improvement to pedestrian accommodations. Better serves side street movements.</td>
</tr>
<tr>
<td>Alternative 2: Restricted Crossing U-Turn EB-WB</td>
<td>79.9</td>
<td>0.5</td>
<td>Yes</td>
<td>3.0</td>
<td>1.0</td>
<td>$4,285,000</td>
<td>5.1 out of 8</td>
<td>Introduces additional u-turn points along US-404. Less accommodating to side-street traffic and pedestrians.</td>
</tr>
</tbody>
</table>
3.5.3 Stage 2 Metric Methodology

Stage 2 metrics report the performance of each alternative derived from an MOE output from a variety of sources. Consistent with Stage 1, the score for each Stage 2 metric is the product of the priority, expressed as the metric weighting, and performance, expressed as the metric MOE score. **Figure 30** depicts the Stage 2 score methodology. The following subsections describe how the Virginia iCAP Tool calculates each Stage 2 metric MOE score. **Appendix C** summarizes the MOE definition, source, and possible score for each Stage 2 metric.

**Figure 30: Stage 2 Scoring Methodology**

![Stage 2 Scoring Methodology Diagram]

**Stage 2 Traffic Operations Metric**

The Virginia iCAP Tool calculates the Stage 2 metric score for four of the six traffic operations MOEs. There is no score associated with the 95th Percentile Queue Length or Maximum Queue Length MOE results. However, the qualitative results should be used to guide the decision-making process for whether an alternative accommodates anticipated travel patterns.

The following subsections present the methodology used to report the Stage 2 metric MOE result and calculate the metric MOE score for the control delay, microsimulation delay, ETT, and v/c ratio MOEs.

**CONTROL DELAY, MICROSIMULATION DELAY, AND EXPERIENCED TRAVEL TIME (ETT)**

The Virginia iCAP Tool returns a volume-weighted delay result expressed as the ratio of the control delay, microsimulation delay, or ETT of each critical approach to the critical approach volume. **Equation 4** presents the volume-weighted delay result calculation, where *delay result* is the alternative control delay, microsimulation delay, or ETT result reported in the Stage 2 Input Worksheet.

**Equation 4: Stage 2 Volume-Weighted Delay Result Calculation**

\[
\text{Volume-Weighted Delay Result} = \frac{\sum \text{Delay Result}_CA \times \text{Volume}_CA}{\sum \text{Volume}_CA}
\]

Where: \(CA = \text{Critical Approach}\)
V/C RATIO
The Virginia iCAP Tool returns the total intersection v/c ratio for each alternative, expressed as the volume-weighted v/c ratio of each alternative intersection. The critical approach selection does not impact the total intersection v/c ratio since v/c ratios are reported at the intersection level.

TRAFFIC OPERATIONS METRIC MOE SCORE
The Traffic Operations Metric MOE Score is calculated for delay and v/c ratio MOEs using minimum value normalization based on the volume-weighted delay or v/c ratio result. The Virginia iCAP Tool uses minimum value normalization to assign the alternative with the lowest delay or v/c ratio a result of one. All other alternatives receive a score between zero and one calculated as a quotient of the lowest delay or v/c ratio result divided by the alternative delay or v/c ratio, as shown in Equation 5.

Equation 5: Stage 2 Traffic Operations Metric MOE Score Calculation
\[
Score = \frac{\text{Minimum} \, \text{[Alternative MOE Result]}}{\text{Alternative MOE Result}}
\]

The total Traffic Operations Metric MOE Score is calculated as the average metric MOE score of the two MOEs selected and has a total possible score of 1. The Virginia iCAP Tool then calculates the Traffic Operations Metric Score as the product of the Traffic Operations Metric MOE Score and the Traffic Operations Metric weighting.

Pedestrian Metric
The Stage 2 Performance Matrix uses the pedestrian accommodation result from VJuST, consistent with the Stage 1 Performance Matrix.

Future versions of iCAP plan to incorporate elements from the Safe System approach to provide more robust analysis of the impacts to pedestrian and bicyclist safety at each intersection approach.

Safety Metric
The Virginia iCAP Tool uses crash modification factors (CMFs) to calculate the anticipated reduction in crashes for an alternative at the study intersection. The FHWA defines a CMF as a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site. A CMF reflects the safety effect of a countermeasure, whether it is a decrease in crashes (CMF below 1.0), increase in crashes (CMF over 1.0), or no change in crashes (CMF of 1.0).

The Virginia iCAP Tool contains a lookup table of CMFs from the SMART SCALE Round 5 Planning Level CMF list and the Virginia State Preferred CMF List. The Virginia iCAP Tool automatically applies the appropriate available CMF for each Stage 2 alternative if available in the lookup table and calculates the anticipated reduction in fatal plus injury crashes based on the crash data input in the Stage 1 Input Worksheet.

If the tool does not include a CMF for a given intersection configuration, the user should refer to the SMART SCALE Round 5 Planning Level CMF list, the Virginia State Preferred CMF list, and the FHWA CMF Clearinghouse in coordination with the VDOT Highway Safety Improvement Program (HSIP) team to identify relevant CMFs to apply for the given countermeasure. If the user identifies an applicable CMF from the sources provided, the user should manually input the CMF value into the CMF input cell and document rationale for CMF selection. Otherwise, the user should input 1.0 into the CMF input cell and document potential qualitative impacts to safety for the given alternative. Figure 31 provides a graphical reference of the process for selecting a CMF for Stage 2 alternatives.

32 http://www.cmfclearinghouse.org/faqs.cfm#q1
33 https://smartscale.org/documents/2022/round_5_cmf_list.pdf
34 https://www.virginiadot.org/business/resources/HSIP/Virginia_State_Preferred_CMF_List.pdf
35 http://www.cmfclearinghouse.org/index.cfm
The alternative with the highest reduction in fatal plus injury crashes, which represents the alternative with the greatest potential safety benefit, is assigned a score of one. Consistent with the Stage 1 Safety Metric MOE Score methodology, the Virginia iCAP tool calculates the Stage 2 Safety Metric MOE Score as a percentage of the highest reduction in fatal plus injury crashes. If an alternative does not reduce the number of fatal plus injury crashes (CMF ≥ 1), the alternative receives a score of zero, as shown in Equation 6.

Equation 6: Stage 2 Safety Metric MOE Score Calculation

\[
Score = \frac{\text{Alternative } R_{F+I}}{\text{Maximum}[\text{Alternative } R_{F+I}]} \\
\text{OR} \\\nScore = 0 \text{ when Alternative } R_{F+I} = 0 \text{ or Alternative } CMF \geq 1
\]

Where: \( R_{F+I} = \text{Reduction in Fatal + Injury Crashes} \)

**Stage 2 Cost Metric**

The Stage 2 Cost Metric is the VJuST-C Planning Level Cost Estimate representing a total estimated engineering and construction for each alternative. Perform a VJuST-C assessment and input the VJuST-C Planning Level Cost Estimate for each Stage 2 alternative. The alternative with the lowest cost estimate is assigned a score of one. All other alternatives receive a score between zero and one as a quotient of the lowest cost estimate divided by the alternative cost estimate, as shown in Equation 7.
Equation 7: Stage 2 Cost Metric MOE Score Calculation

\[ Score = \frac{Minimum [Cost Estimate]}{Alternative Cost Estimate} \]

3.5.4 Stage 2 Alternative Selection and Justification

Once the user inputs Stage 2 traffic operations results, SMART SCALE fatal and injury crash CMFs, and the VJuST-C cost estimates, the Virginia iCAP Tool calculates a Total Stage 2 Score for each alternative. The Total Stage 2 Score is the sum of each metric score and is displayed out of the total possible score, the sum of metric weightings. In the Total Stage 2 Score column, the tool applies a color scale to the Total Stage 2 Score cells based on the Total Stage 2 Score of each alternative.

Figure 33 provides an example for a total possible score of ten consistent with the metric weightings applied during Stage 1 of Traffic Operations = two, Pedestrian = two, Safety = three, and Stage 2 Cost = three. The total score for each alternative is provided and formatted to show the differentiation between high- and low-scoring alternatives.

Although the total score and color scale is useful for identifying the highest-ranking alternatives, the user should not select the alternative for submission to VDOT solely on the Total Stage 2 score. Refer to Section 3.4.4 for guidance in determining justification for selecting a preferred alternative.

3.6 Reporting

The Virginia iCAP Tool provides a consistent framework to document an intersection control evaluation. The Virginia iCAP Assessment Output sheets summarize all necessary Virginia iCAP Tool inputs and outputs to be submitted to the reviewer. The user will input the evaluator name and evaluation date on the first iCAP Assessment Output sheet. To export the Virginia iCAP Assessment Output sheets to PDF, the user will press the Export Virginia iCAP Assessment to PDF button on the Stage 2 Performance Matrix sheet, shown in Figure 32.

Refer to Section 2.4 for the list of items to be submitted to the VDOT DTE, or designee as part of a full Virginia iCAP Assessment.

Figure 32: Export Virginia iCAP Assessment to PDF Button
Figure 33: Example Stage 2 Metric Performance Matrix Results

### Traffic Operations

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Control Delay</th>
<th>95th Percentile Queue Length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Result</td>
<td>Score</td>
</tr>
<tr>
<td>Alternative 1</td>
<td>Bowtie NB-SB</td>
<td>42.8</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>Restricted Crossing U-Turn EB-WB</td>
<td>79.9</td>
</tr>
</tbody>
</table>

### Pedestrian

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>V-JuST Accommodation Compared to Conventional</th>
<th>Pedestrian Metric MOE Score</th>
<th>Annual Number of F+I Crashes</th>
<th>SMART SCALE F+I CMF</th>
<th>Annual F+I Crash Reduction (Number of Crashes)</th>
<th>Safety Metric MOE Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 1</td>
<td>Bowtie NB-SB</td>
<td>+</td>
<td>1.0</td>
<td>0.91</td>
<td>0.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>Restricted Crossing U-Turn EB-WB</td>
<td>0</td>
<td>5.0</td>
<td>0.65</td>
<td>2.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### Stage 2 Cost

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>V-JuST-C Total Estimated Engineering and Construction Cost</th>
<th>Stage 2 Cost Metric MOE Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 1</td>
<td>Bowtie NB-SB</td>
<td>$8,400,000</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>Restricted Crossing U-Turn EB-WB</td>
<td>$4,285,000</td>
</tr>
</tbody>
</table>

### Preferred Alternative Selection for Submission to VDOT

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Stage 2 Total Score</th>
<th>Preferred Alternative?</th>
<th>Justification*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 1</td>
<td>Bowtie NB-SB</td>
<td>6.4 out of 10</td>
<td>Yes</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>Restricted Crossing U-Turn EB-WB</td>
<td>7.0 out of 10</td>
<td>No</td>
</tr>
</tbody>
</table>
3.7 Troubleshooting Tool Issues

The Virginia iCAP Tool is an Excel®-based spreadsheet tool that uses macros for some features. The tool was developed in Microsoft Excel® for Microsoft 365, which saves macro-enabled Excel® files in the .xlsm format. Excel® 2007 and later versions can open .xlsm files by default, so it is not recommended to use Excel® versions earlier than Excel® 2007. When opening the Virginia iCAP Tool, be sure to press the Enable Content button to enable macros.

The following sections provide guidance for troubleshooting issues that may arise when using macro functions.

**Enabling Events**

Some macro-based features in the tool, such as the generation of ETT spreadsheets during Stage 2, require events to be enabled. The user should select the button located on the Instructions sheet (shown in Figure 34) if the Virginia iCAP Tool is not generating ETT spreadsheets when the alternatives are selected in the Stage 2 Input Worksheet.

Figure 34: Enable Events Button

If ETT Sheets are not populating click here to enable events

**Import VJuST Results Tool**

VJuST Results import macros can be used on the Stage 1 Input Worksheet and Stage 1 Performance Matrix to streamline VJuST data entry. Both features require the latest VJuST version to import results. The latest version of VJuST can be downloaded for free on the VDOT Innovative Intersections and Interchanges website.36

---

36 [https://www.virginiadot.org/innovativeintersections/](https://www.virginiadot.org/innovativeintersections/)
Chapter 4. Assessment Techniques and Strategies

Virginia iCAP provides a holistic framework and planning-level tool to assist with consistent performance-based alternatives assessments. The Virginia iCAP Tool is built to consistently document the decision-making process for the alternatives selected and is compatible with numerous innovative intersection and interchange configurations. While the alternatives assessment framework provided in iCAP is universal, the Virginia iCAP Tool does not account for all possible intersection and interchange configurations nor project-specific details. This chapter outlines several assessment techniques and strategies that may be presented to practitioners involved in unique projects or studies. Given that the techniques and strategies presented in this chapter are non-exhaustive, project teams should exercise engineering judgment while implementing the Virginia iCAP process to holistically evaluate alternatives in a data-driven and consistently documented manner. Furthermore, Appendix A includes five Virginia iCAP case studies that demonstrate the application of the Virginia iCAP process and offer practitioners further guidance in faithfully implementing the Virginia iCAP approach.

4.1 Partial and Hybrid Innovative Intersection Designs

VJuST includes full and partial innovative intersection and interchange designs; however, sometimes partial or hybrid designs that are not included in VJuST may be considered. Partial designs restrict and/or reroute movements for a select number of intersection movements rather than all major and minor street movements. Partial innovative intersection and interchange designs may be considered where full access is desired for a portion of the intersection, which may occur where minor street volumes for one approach are higher or where access is desired to destinations along one roadway segment. Figure 35 depicts a partial RCUT that restricts side-street through and left-turn movements from one approach.

Figure 35: Partial RCUT Example
Hybrid innovative and interchange designs may combine design principles from several innovative configurations. For example, a traditional MUT restricts left-turn movements from one or both roads, while a traditional thru-cut restricts side-street through movements. Figure 36 depicts a hybrid MUT/thru-cut that restricts main street left-turns and side-street through movements.

The user should exercise caution when evaluating partial and/or hybrid designs using VJuST since the VJuST pedestrian and safety metric methodologies assume full innovative intersection and interchange designs. If partial or hybrid designs are considered during Stage 1, the user must provide written justification of pedestrian and safety impacts to supplement the Stage 1 Performance Matrix.

Furthermore, the user should exercise caution when evaluating partial and/or hybrid designs using VJuST-C as the cost estimating assumptions for the standard innovative intersection configuration may not be applicable to the partial and/or hybrid design.

Figure 36: Hybrid MUT/Thru-Cut Example

4.2 Analyzing Multiple Intersections

VJuST and the Virginia iCAP Tool are most applicable at isolated intersections or interchanges and do not account for the influence of adjacent intersections on traffic patterns. However, whether due to travel patterns or the proximity of adjacent intersections, the purpose and need for a Virginia iCAP assessment may require the analysis of multiple intersections. In these cases, each intersection should be evaluated separately with a unique set of VJuST and Virginia iCAP Tool spreadsheets and discussed during the scoping meeting. Written justification should be documented in the Stage 1 Performance Matrix to document any corridor considerations.
4.3 Impacts to Adjacent Intersections

VJuST does not consider how closely spaced intersections impact operations or safety. To account for such impacts of alternatives in a Virginia iCAP assessment, the user should provide qualitative justification in the Stage 1 Performance Matrix for each alternative, describing any geometric, operational, safety, and/or access management impacts to adjacent intersection(s).

4.4 Analyzing Five-Legged Intersections

VJuST, VJuST-C, and the Virginia iCAP Tool are limited to intersection alternatives with up to four legs. As a result, the tools should not be used to analyze five-legged intersection alternatives for a Virginia iCAP assessment. The methodology to evaluate five-legged intersections should be agreed upon with the VDOT DTE, or designee, at the project scoping meeting. Applications should consider one of the following methodologies:

- If more than three potential alternatives are identified, the project team should create a project specific performance matrix based on the ones included in the Virginia iCAP Tool with the following information:
  - v/c ratio reported from a traffic analysis tool according to the VDOT TOSAM
  - number of conflict points calculated using Highway Safety Manual (HSM) methodologies
  - qualitative description of pedestrian accommodation

- If fewer than three potential alternatives are identified, the project team should consider skipping Stage 1 and proceeding to Stage 2 to analyze all alternatives using a traffic analysis tool according to the VDOT TOSAM.

4.5 Analyzing Multiple Peak Periods

Depending on the differences observed in travel patterns between peak periods, a Virginia iCAP assessment may require the analysis of multiple peak periods. In such cases, the user should evaluate each peak period separately, with a unique set of VJuST, VJuST-C, and Virginia iCAP spreadsheets. When selecting alternatives to advance to Stage 2 analysis or when selecting the preferred alternative, the user should consider the results for each peak period scenario analyzed.
APPENDIX A

Virginia iCAP Case Studies
Appendix A: Virginia iCAP Case Studies

Five Virginia iCAP case studies outline the use of the Virginia iCAP process for unique example projects and provide guidance in determining iCAP applicability, demonstrating the use of the iCAP tool, and using engineering judgment and critical thinking to faithfully implement the iCAP process. Each case study, as shown in Table 1, demonstrates how project teams can appropriately account for unique project characteristics within the Virginia iCAP process. Please note that cross streets are intentionally generalized for the purposes of these case studies.

Table 1: Case Study Summary

<table>
<thead>
<tr>
<th>#</th>
<th>Location</th>
<th>Existing Intersection Control</th>
<th>Project Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>US Route 460 at Route A</td>
<td>TWSC</td>
<td>Intersection located on the APN experiencing congestion at both minor approaches with proximity to a large interchange between two major state corridors.</td>
</tr>
<tr>
<td>2</td>
<td>US Route 234 at Route A</td>
<td>Signalized</td>
<td>Intersection with congested principal arterial adjacent to multiple anticipated developments and a multi-use path crossing.</td>
</tr>
<tr>
<td>3</td>
<td>US Route 11 at Street A, Street B, and Street C</td>
<td>Signalized</td>
<td>Five-leg intersection near school providing a designated truck route while suffering from operational challenges and safety concerns.</td>
</tr>
<tr>
<td>4</td>
<td>US Route 1 at Route A and Route B</td>
<td>Signalized</td>
<td>Two closely spaced intersections along the APN with notable morning and evening peak travel patterns.</td>
</tr>
<tr>
<td>5</td>
<td>US Route 29 at Route A</td>
<td>TWSC</td>
<td>Unsignalized intersection at an interchange with notable congestion.</td>
</tr>
</tbody>
</table>

For the purposes of this manual, each case study intends to serve as a general guide and may not be fully inclusive of all details required for each alternative when providing Stage 1 and Stage 2 sketches and documentation. A full Virginia iCAP assessment requires a comprehensive analysis for all alternatives analyzed at each stage of the process. Project teams should treat these case studies as examples for navigating the iCAP assessment process and not as full reports. Each case study follows the iCAP flowcharts provided in this Manual and uses icons (ex. A.1.1) to connect actions taken during the case study with the applicable flowchart step. The iCAP flowcharts are provided again for quick reference.

- Applicability flowchart: Figure 1
- Stage 1 flowchart: Figure 2
- Stage 2 flowchart: Figure 3
Virginia iCAP assessment is required. Complete Virginia iCAP Applicability Form.

A.1 Location

A.1.1 Is the intersection or interchange located on VDOT’s Arterial Preservation Network (APN)?

A.1.2 Is the intersection or interchange located on a VDOT-maintained roadway and a signal is recommended?²

A.1.3 Stage 1 Virginia iCAP assessment is required along with warrant study per IIM-TE-387. Complete Virginia iCAP Applicability Form.

A.2 Purpose and Need

A.2.1 Does the intersection or interchange purpose and need indicate traffic control should be evaluated?

A.3 Performance Based Practical Design

A.3.1 If signalized, can operational and safety issues be resolved with changes to signal phasing and timing?¹

A.4 Virginia iCAP assessment is required. Complete Virginia iCAP Applicability Form.

A.5 Complete Virginia iCAP Tool General Input Worksheet and Conduct Scoping Meeting.

LEGEND

Applicable Tool
Applicable Reference Document (Manual, IIM, Form)

Notes:
¹ Include coordination with a VDOT Signal and Freeway Operations Engineer (SFOE)
² If initial screening of traffic volumes and crashes reveal a signal is not likely to be warranted, then the Virginia iCAP process and signal warrant study are not required.

Figure 1: Virginia iCAP Applicability Flowchart
1.5 Stage 2: Alternatives Assessment

LEGEND

Applicable Tool

Figure 2: Virginia iCAP Assessment Stage 1 Flowchart
STAGE 2: ALTERNATIVES ASSESSMENT

2.1 Additional Data Collection
Input data into the Virginia iCAP Tool Stage 2 Input Worksheet

2.2 Operations and Safety Performance Evaluation
2.2.1 Perform operational analysis using appropriate tool per TOSAM
2.2.2 Input results into the Virginia iCAP Tool Stage 2 Input Worksheet
2.2.3 Review CMF for each potential alternative

2.3 Stage 2 Sketch and Cost
2.3.1 Create Stage 2 refined sketch for each alternative
2.3.2 Complete Stage 2 construction cost estimate for each alternative in VJuST-C

2.4 Metric Performance Ranking
2.4.1 Evaluate and rank alternatives in the Virginia iCAP Tool Stage 2 Performance Matrix

2.5 Document selected alternative and submit to VDOT for approval

LEGEND
Applicable Tool
Applicable Reference Document (Manual, IIM, Form)

Notes:
1 May include coordination with VDOT Highway Safety Improvement Program (HSIP) team

Figure 3: Virginia iCAP Assessment Stage 2 Flowchart
Case Study #1: US Route 460 at Route A

This example project illustrates the application of the iCAP process at an intersection located along the APN that experiences congestion on the minor approaches. The study location is located next to a large interchange between two major state corridors, which introduces the need to not only consider right-of-way impacts but also potential operational impacts to the nearby ramps.

The intersection in this case study is a real location, however, for the purposes of Virginia iCAP policy and tool demonstration some data and location characteristics have been modified.

1.1 Project Introduction

1.1.1 Location Overview
This case study location is in Nottoway County, Virginia at the intersection of US Route 460 (Colonial Trail Highway) and Route A (Minor Street). US Route 460 is a four-lane, divided, rural principal arterial on the APN and Route A (Minor Street) is at two-lane, undivided, major collector. This intersection, shown in Figure 4, provides access to the interchange of US Route 460 and US Route 360 as well as the local street network located south of the study intersection. The existing lane designations and traffic control are shown in Figure 5.

Figure 4: Aerial of Study Intersection
1.1.2 Purpose & Need

Identifying a project’s purpose and need helps the project team define project priorities and determine iCAP applicability. The project team identified the following concerns:

- **Traffic Operations**: Route A (Minor Street) currently experiences congestion during both peak periods, primarily due to heavy through and left-turn movements.
- **Safety**: There were 19 total crashes recorded at the intersection between 2016 and 2020. 16 of the 19 total crashes were angle collisions.

The historic crash data, along with the number of conflict points present at the existing intersection, and the presence of a nearby interchange led the project team to consider innovative intersection designs.
1.2 iCAP Applicability

The project team referenced the iCAP Tool “Applicability Flowchart” provided in Figure 1 to determine if an iCAP assessment is required.

A.1.1 Determine if the intersection is located on the APN

US Route 460 is on the APN; therefore proceed to step A.2.1.

A.2.1 Determine if the project purpose and need indicate traffic control should be evaluated

A change in traffic control at the intersection should be a consideration due to existing congestion and safety issues on the minor approaches; therefore, proceed with step A.3.1.

A.3.1 Determine if issues at the location can be resolved with changes to signal timing and phasing

This step does not apply, as the study location is currently stop-controlled. Therefore, the intersection requires the full iCAP assessment and the project team should continue to the next step: A.4.

A.4 Complete Virginia iCAP Applicability Form

The form generated for this case study location is shown in Figure 6.

Once the VDOT District Traffic Engineer approved the iCAP Applicability Form, the project team scheduled a scoping meeting with VDOT and other project stakeholders.

---

1 VDOT Arterial Preservation Network (APN) Map
https://vdot.maps.arcgis.com/apps/webappviewer/index.html?id=6a024b2739e44b5b8599d86aa3b2c6d7
### VIRGINIA iCAP APPLICABILITY FORM

Evaluator: VDOT  
Date: 8/12/2022

#### PROJECT LOCATION

<table>
<thead>
<tr>
<th>Locality/County:</th>
<th>Nottoway County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location:</td>
<td>US Route 460 &amp; Route XX</td>
</tr>
</tbody>
</table>

Is the project located on the Arterial Preservation Network (APN)?

- Yes

#### A) APPLICABILITY FOR LOCATIONS ON THE APN

**PROJECT PURPOSE AND NEED**

- Does the project purpose and need indicate intersection or interchange control should be evaluated?
  - Yes

**PERFORMANCE BASED PRACTICAL DESIGN**

- If the existing intersection is signalized, can operational and safety issues be resolved with changes to signal phasing and timing?
  - Not Applicable

#### B) APPLICABILITY FOR LOCATIONS OFF THE APN

- Is the intersection or interchange located on a VDOT-maintained roadway? **AND**
- Is a signal recommended as the intersection traffic control?
  - If Yes to both, conduct Stage 1 Virginia iCAP assessment and warrant study per the latest version of IIM-TE-387
  - If No to either, a Virginia iCAP assessment is not required

### ASSESSMENT REQUIREMENT AND APPROVAL

Document the analysis required and submit to the VDOT District Traffic Engineer or designee for approval.

<table>
<thead>
<tr>
<th>Required Assessment:</th>
<th>Full Virginia iCAP Assessment Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reason for Exclusion:</td>
<td></td>
</tr>
<tr>
<td>Justification:</td>
<td></td>
</tr>
</tbody>
</table>

---

Figure 6: Populated iCAP Applicability Form
1.3 Existing Needs

Complete Virginia iCAP Tool General Input Worksheet

To prepare for the scoping meeting, the project team populated the General Input Worksheet in the iCAP tool. Reference Section 3.2.2 of the iCAP Manual for guidance on completing this section.

The project team utilized the VTrans Mid-Term Needs and Priorities Map\(^2\) to identify any transportation needs at and in the vicinity of the study location as shown in Figure 7. This information was populated into the VTrans Needs and Priorities table included in the General Input Worksheet, shown in Table 2. In addition to the identified VTrans Needs and Priorities, the project team input the following information into the General Input Worksheet:

- **Existing and future V/C ratios\(^3\)**
  - Route 1 existing V/C of 0.38
  - Route 1 future V/C of 0.80
- **PSI segment and intersection ranking\(^4\)**
  - No PSI segments
  - No PSI intersections
- **PSAP data\(^5\)**
  - Not a PSAP corridor
  - Not a bicycle and pedestrian generator

---

\(^2\) InteractVTrans Map Explorer. https://vtrans.org/interactivetrans/map-explorer
Figure 7: 2019 VTrans Prioritized Mid-Term Needs
### 1.4 Metric Weighting

Prior to the scoping meeting, the project team developed draft metric weights to be used when ranking design alternatives. These metrics are all important to maintaining a safe and efficient highway system, however, each project has a different purpose and need. The weighting system allows analysts to compare alternatives in a way that prioritizes the specific needs of a project, while still considering and valuing each metric. The project purpose and need, the historic crash data, the identified VTrans priorities, and preliminary engineering judgment were used to determine these draft metric weights. The metric weights developed for this project are shown in Table 3. For more information on metric weighting, reference Section 3.3 of the iCAP Manual.

#### Table 3: Project Metric Weighting

<table>
<thead>
<tr>
<th>Metric Weighting</th>
<th>Metric</th>
<th>Priority</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Operations</td>
<td>High (3)</td>
<td>The study was initiated due to existing congestion along the minor approaches. Capacity preservation was flagged as a VTrans priority at the Corridor of Statewide Significance (CoSS) level.</td>
<td></td>
</tr>
<tr>
<td>Pedestrian</td>
<td>Low (1)</td>
<td>Lack of pedestrian activity, facilities, and generators at the study intersection and along the US Route 460 corridor.</td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>Moderate (2)</td>
<td>19 crashes were recorded at the study location within the 5-year period. Safety improvement was flagged as a VTrans priority at the district level.</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>Low (1)</td>
<td>US Route 460 is classified as a corridor of statewide significance. A specific funding limitation was not identified.</td>
<td></td>
</tr>
</tbody>
</table>
The draft metric weights developed while completing the General Input Worksheet, as well as the justifications behind each metric priority ranking, were presented at the scheduled scoping meeting. They were revised based on feedback received from VDOT and other project stakeholders. Once approved by VDOT, the metric weights were then used in the iCAP analysis.

1.5 Scoping Meeting

Following the approval of the iCAP Applicability Form, the project team held a scoping meeting and discussed the project purpose and need, study limits, data requirements, metric measures of effectiveness (MOEs), and analysis tools required to perform the iCAP assessment, per Chapter 9 of the VDOT Traffic Operations and Safety Manual (TOSAM) and Section 2.2.1 of the iCAP Manual. The main outcomes from the scoping meeting are summarized below:

- **Study Area Limits:**
  - The project team and VDOT staff decided that the analysis would focus solely on the intersection of US Route 460 and Route A (Minor Street) since the minor approaches are the only ones currently experiencing congestion.

- **Draft Metric Weighting:**
  - The DTE and other VDOT stakeholders felt that the metric weights aligned with the needs and priorities outlined in the General Input Worksheet, so they were approved for use with the iCAP tool.

- **Study MOEs:**
  - Control delay and 95th percentile queue length were selected as the MOEs for the analysis. The group collectively agreed that these were the most appropriate MOEs to evaluate performance at the study intersection due to the congestion experienced on both northern and southern stop-controlled approaches.

- **Analysis Tools:**
  - The project team populated the VDOT Software Selection Tool (SST) Input Form with the location information and MOE selection and indicated that the intersection operates under undersaturated conditions.
  - The results from the VDOT SST indicated that Synchro was the most appropriate software to conduct the analysis.

---

• **Analysis Period:**
  - The project team and VDOT staff decided that the intersection alternatives would be evaluated for the 2040 horizon year in accordance with the available TDM horizon. The project team agreed to conduct turning movement counts at the study intersection to develop future no-build volumes prior to conducting the analysis.
  - The intersection is reported to operate worse during the PM peak period. As a result, the project team proposed conducting the iCAP analysis for the PM peak hour only.

• **Data Collection:**
  - All existing conditions data was collected in year 2020. Historic crash data was obtained for the period between 2016 and 2020.

• **Analysis Alternatives:**
  - The DTE and other VDOT stakeholders expressed that they would prefer that the major movements remain free flowing to minimize operational impacts to the interchange.

### 1.6 Virginia iCAP Assessment Stage 1

The project team referenced the iCAP Tool “Stage 1 Flowchart” provided in Figure 2 to complete this phase of the assessment.

#### 1.6.1 Data Collection

**Input data into the Virginia iCAP Stage 1 Input Worksheet**

**Traffic Data**

Consistent with TOSAM and the Virginia iCAP process, the project team agreed upon the time periods, days, modes, and locations of count data to be taken during the scoping meeting. The scoping meeting was held in late October, so the count timeframe was decided to be early January after the holiday season. The project team proposed the use of historic AADT data from VDOT count books to generate the volume growth rate used to generate 2040 volumes. The DTE and other VDOT stakeholders approved this methodology. The existing (2020) and future (2040) PM peak hour turning movement counts are shown in Figure 8.

**Project-Specific Value:**

2040 traffic volumes were generated using a 2% annual growth rate, which was determined using historic count data. The proposed growth rate was compared to the predicted growth in the region and approved by the DTE.
There are currently no bicycle, pedestrian, or transit facilities at the intersection or along either corridor. Additionally, there were no pedestrians or bicyclists present during the completion of turning movement counts. This is most likely due to the rural setting of the study intersection, located far from any identifiable pedestrian or bicycle generators. As a result, the project team and VDOT stakeholders determined that pedestrian and bicyclist needs were not a priority for this location.

The project team populated the Stage 1 Input Worksheet with the 2040 PM peak hour traffic volumes, the existing multimodal accommodations, and the historic crash data.

1.6.2 Stage 1 Operations & Safety Screening

The Stage 1 performance matrix screens intersection alternatives based on four metrics:

- Traffic operations
- Pedestrian
- Safety
- Stage 1 cost

These metrics are reported from the Virginia Junction Screening Tool (VJuST).

Select alternatives in VJuST

When populating the VJuST Input Worksheet, the project team excluded several intersection designs due to right-of-way concerns and general infeasibility given the roadway facility types and traffic patterns. The excluded intersection types and the rationale for excluding them is presented in Table 4.
### Table 4: Excluded Intersection Alternatives

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Considered?</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowtie</td>
<td>No</td>
<td>Right-of-way and spacing constraints.</td>
</tr>
<tr>
<td>Continuous Green-T</td>
<td>No</td>
<td>Unable to accommodate traffic pattern. Used at three-legged intersections.</td>
</tr>
<tr>
<td>Center Turn Overpass</td>
<td>No</td>
<td>Not feasible for roadway facility type and existing traffic patterns.</td>
</tr>
<tr>
<td>Echelon</td>
<td>No</td>
<td>Not feasible for roadway facility type. Right-of-way and spacing constraints.</td>
</tr>
<tr>
<td>Displaced Left Turn</td>
<td>No</td>
<td>Not feasible for roadway facility type and existing traffic patterns.</td>
</tr>
<tr>
<td>Quadrant Roadway</td>
<td>No</td>
<td>Unable to accommodate traffic patterns. Right-of-way and spacing constraints.</td>
</tr>
<tr>
<td>Single Loop</td>
<td>No</td>
<td>Right-of-way and spacing constraints.</td>
</tr>
<tr>
<td>Split Intersection</td>
<td>No</td>
<td>Insufficient intersection spacing. Right-of-way and spacing constraints.</td>
</tr>
<tr>
<td>Mini Roundabouts</td>
<td>No</td>
<td>Not feasible for roadway facility type.</td>
</tr>
</tbody>
</table>

**Key Consideration:**

In addition to the intersection alternatives highlighted in the table above, the project team did not consider any interchange alternatives due to right-of-way and spacing constraints, primarily due to the existing interchange located less than 1000’ west of the study intersection.

The following alternatives were selected for consideration in VJuST: Conventional, Median U-Turn (MUT), Partial MUT, Restricted Crossing U-Turn (RCUT), Thru-Cut, Roundabout, and Two-Way Stop Control.

### 1.6.3 VJuST Assumptions

The project team documented the following assumptions used when conducting the VJuST analysis:

- The analysis was conducted using 2040 PM peak hour volumes.
- All adjustment factors and the truck passenger-car equivalent (PCE) factor were set to the default suggested values.
- Although it was assumed that the base number of through lanes remained the same as existing across all alternatives, the presence of turn lanes and lane sharing was altered for each alternative, primarily for both minor approaches.
- Several of the alternative intersection designs considered featured a U-turn movement in the western leg of the intersection. Due to spacing constraints, it was assumed that vehicles making the U-turn did so at the next median opening of US Route 460/US Route 360, approximately 3,200’ west of the study area intersection.
- Both the MUT and Partial MUT alternatives in VJUST were evaluated under the assumption that the primary intersection is signalized. This assumption cannot be changed, so it was taken into consideration when evaluating the results of the VJUST analysis.
- In addition to the various intersection designs considered, the two-way stop control alternative was evaluated with additional turn lanes on both minor street approaches as a potential future build scenario.
1.6.4 Stage 1 Sketches

Create Stage 1 sketch for potentially viable alternatives

Stage 1 sketches were produced for each viable alternative evaluated in VJuST. The purpose of the Stage 1 sketch is to identify any high-level design constraints that could deem certain alternatives unviable. Reference Section 2.2.2 of the iCAP Manual for more information on the Stage 1 Conceptual Layout guidelines. Sketches were created for the following intersection alternatives:

- Conventional
- Median U-Turn
- Partial Median U-Turn
- Restricted Crossing U-Turn
- Thru-Cut
- Roundabout
- Two-Way Stop Control

For the purposes of this manual, a sample Stage 1 sketch is only provided for the selected alternative. A full iCAP analysis should include designs for each alternative selected for consideration. Figure 9 illustrates an example of a Stage 1 sketch for the RCUT alternative.

![Figure 9: RCUT Stage 1 Sketch](image)

1.6.5 Metric Performance Ranking

Evaluate and rank alternatives using the Virginia iCAP Tool Stage 1 Performance Matrix

A condensed version of the completed Stage 1 Performance Matrix imported from VJuST is shown in Figure 10. Reference Section 3.4.2 of the iCAP Manual for guidance on interpreting the values included in the Stage 1 Performance Matrix.
## STAGE 1 PERFORMANCE MATRIX

*Case Study: Route 460 & Route A*

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations</th>
<th>Pedestrian</th>
<th>Safety</th>
<th>Stage 1 Cost</th>
<th>Total Score</th>
<th>Selection for Stage 2 and Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-Way Stop Control</td>
<td>0.80</td>
<td>--</td>
<td>0</td>
<td>48</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Conventional</td>
<td>0.47</td>
<td>0.5</td>
<td>0</td>
<td>48</td>
<td>0.0</td>
<td><strong>3</strong> No: Does not improve safety.</td>
</tr>
<tr>
<td>Median U-Turn EB-WB</td>
<td>0.39</td>
<td>0.7</td>
<td>+</td>
<td>20</td>
<td>1.0</td>
<td><strong>5.6</strong> Yes: Improves operations and reduces conflict points.</td>
</tr>
<tr>
<td>Partial Median U-Turn EB-WB</td>
<td>0.17</td>
<td>1.0</td>
<td>+</td>
<td>28</td>
<td>0.7</td>
<td><strong>5.9</strong> No: Highest overall score, but may not address minor approach concerns, especially since evaluated in VIJUSTR as signalized.</td>
</tr>
<tr>
<td>Restricted Crossing U-Turn EB-WB</td>
<td>0.35</td>
<td>0.7</td>
<td>0</td>
<td>20</td>
<td>1.0</td>
<td><strong>5.1</strong> Yes: Performs as well as the MUT in every category except pedestrian accommodation, which isn’t critical at this location.</td>
</tr>
<tr>
<td>Thru-Cut</td>
<td>0.48</td>
<td>0.5</td>
<td>0</td>
<td>28</td>
<td>0.7</td>
<td><strong>3.9</strong> Yes: Being moved forward because MUT alternatives were evaluated as signalized; This option may address operations better.</td>
</tr>
<tr>
<td>Two-Way Stop Control</td>
<td>0.67</td>
<td>0.2</td>
<td>0</td>
<td>48</td>
<td>0.0</td>
<td><strong>2.1</strong> No: Does not sufficiently address operations issue nor reduce conflict points.</td>
</tr>
</tbody>
</table>

**Figure 10: Stage 1 Performance Matrix**
Of the six total alternatives considered in Stage 1, three were selected for consideration in Stage 2: MUT, RCUT, and Thru-Cut.

- **MUT:**
  - The MUT advanced to Stage 2 due to the anticipated benefits of rerouting of all left-turn movements, which not only reduced the number of conflict points at the intersection, but also resulted in a lower V/C ratio.
  - Removing the left-turning movement from the median crossing may also reduce the amount of delay experienced by vehicles making the through movement from either minor approach.

- **RCUT:**
  - The RCUT alternative was moved forward due to the expected V/C ratio improvements and the reduction in the number of total conflict points at the intersection.
  - It scored lower than the MUT alternative due to having fewer pedestrian accommodations. However, given the lack of pedestrian activity along the corridor, this was not a concern.

- **Thru-Cut:**
  - The Thru-Cut alternative was moved forward because it completely reroutes both minor approach through movements, which were the main cause for safety concerns at the study intersection.
  - This alternative has a higher maximum V/C ratio than both the MUT or RCUT. However, it is important to note that the MUT alternative was analyzed under the assumption that the primary intersection would be signalized.
  - The Thru-Cut alternative does not improve existing pedestrian accommodations. However, given the lack of pedestrian activity along the corridor, this was not a concern.

The remaining alternatives were not moved forward for the following reasons:

- **Conventional Intersection:**
  - The conventional intersection did not improve the number of conflict points at the study intersection.
  - The operational performance improvements were similar or better in other evaluated alternatives.

- **Two-Way Stop Control:**
  - The two-way stop control alternative was not moved forward due to its high V/C ratio and the lack of expected safety improvements.

- **Partial MUT:**
  - The partial MUT only restricts left-turns from the major approaches and, therefore, is not expected to effectively address the safety and operational issues stemming from the minor street through and left-turn movements.

The project team selected the MUT, RCUT, and Thru-Cut for Stage 2 Analysis in the Stage 1 Performance Matrix and proceeded to the next step: 1.5 (Continue to Stage 2: Alternatives Assessment).

### 1.7 Virginia iCAP Assessment Stage 2

The project team referenced the iCAP Tool “Stage 2 Flowchart” provided in Figure 3 to complete this phase of the assessment.

#### 1.7.1 Additional Data Collection

No additional data was required so the project team proceeded to the next step: 2.2 (Operations and Safety Performance Evaluation).
1.7.2 Operations & Safety Performance Evaluation

2.2.1 Perform operational analysis using appropriate tool per TOSAM

The MUT, RCUT, and Thru-Cut alternatives were modeled and evaluated using Synchro and following the guidelines outlined in TOSAM. The project team generated HCM 6th edition reports for each alternative for use in the iCAP Stage 2 input worksheet. Prior to transferring the Synchro outputs into the input worksheet, the sheet was populated with the agreed-upon MOEs and the critical approach information.

2.2.2 Input results into the Virginia iCAP Tool Stage 2 Input Worksheet

The project team selected the 95th Percentile Queue Length and Control Delay MOEs and completed the critical approach inputs.

Key Consideration:
Although the project was initiated due to congestion on the minor approaches, the major approaches were also selected as critical approaches because US Route 460 is a corridor of statewide significance. As a result, the operational performance for all four approaches were determined to be critical for evaluating alternatives.

QUEUING

Although the study area consists of one primary intersection, all alternatives include a two-stage turning movement with an additional queuing area in the median opening. As a result, queues at this location needed to be considered when evaluating each alternative. To determine whether queues are accommodated for each approach, the project team compared the HCM 95th Percentile Queues provided in the Synchro reports, like those shown in Table 5, to the length of the storage provided for the respective movement.

| Table 5: Report Outputs from Synchro for RCUT Alternative |
|-----------|------|------|-----|
| Lane Group | Movement Flow (vph) | NBL | NBT | 313 |
| Total Delay | - | - | 17.8 |
| HCM 95th %tile Q(veh) | - | - | 3.1 |
| Internal Link Distance (ft) | - | - | 462 |
| Turn Bay Length (ft) | - | - | - |

# 95th percentile volume exceeds capacity, queue may be longer.

In the RCUT scenario, there is only one northbound approach. The results of the Synchro analysis found that the 95th Percentile Queue for the northbound approach is approximately three vehicles long. This queue length can be accommodated in the available storage space, so the 95th Percentile Queue Length MOE Table was populated accordingly as shown in Table 6.
Table 6: 95th Percentile Queue Inputs for the RCUT Alternative

<table>
<thead>
<tr>
<th>95th Percentile Queue Length MOE Results</th>
<th>Input MOE</th>
<th>Northbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td># of Approaches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Queues Accommodated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total Amount</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>Restricted Crossing U-Turn EB-WB</td>
<td>95th Percentile Queue Length</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Queues Acceptable?</td>
</tr>
</tbody>
</table>

In the No-Build (Base) scenario, there are two northbound approaches: one at the intersection of US Route 460 Eastbound and Route A and one at the median opening at the intersection with US 460 Westbound. The results of the Synchro analysis, shown in Table 7, found that the 95th Percentile Queue for the median northbound approach is 4.5 vehicles long. This queue cannot be accommodated in the available median storage space. However, the other northbound queue can be accommodated. Therefore, the project team indicated that only one queue was accommodated in the 95th Percentile Queue Length MOE as shown in Table 8.

Table 7: Report Outputs from Synchro for the Base Condition (TWSC)

<table>
<thead>
<tr>
<th>Lane Group</th>
<th>NBL</th>
<th>NBT</th>
<th>NBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement Flow (vph)</td>
<td>157</td>
<td>69</td>
<td>-</td>
</tr>
<tr>
<td>Total Delay</td>
<td>-</td>
<td>33.8</td>
<td>-</td>
</tr>
<tr>
<td>HCM 95th %tile Q(veh)</td>
<td>-</td>
<td>4.5</td>
<td>-</td>
</tr>
<tr>
<td>Internal Link Distance (ft)</td>
<td>-</td>
<td>86</td>
<td>-</td>
</tr>
<tr>
<td>Turn Bay Length (ft)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

# 95th percentile volume exceeds capacity, queue may be longer.

Table 8: 95th Percentile Queue Inputs for the Base Condition (Two-Way Stop Control)

<table>
<thead>
<tr>
<th>95th Percentile Queue Length MOE Results</th>
<th>Input MOE</th>
<th>Northbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td># of Approaches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Queues Accommodated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total Amount</td>
</tr>
<tr>
<td>Base Condition</td>
<td>Two-Way Stop Control</td>
<td>95th Percentile Queue Length</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Queues Acceptable?</td>
</tr>
</tbody>
</table>

Key Consideration:

Because the MUT, RCUT, and Thru-Cut alternatives all included a U-Turn movement at the eastern crossover, the project team included an additional eastbound approach to all three build alternatives to capture any queuing that may result from vehicles waiting to make the U-turn movement onto westbound US Route 460.
CONTROL DELAY
In addition to queueing information, the reports generated from Synchro included information on control delay. The project team populated the Stage 2 Input Worksheet with the control delays for both the base condition and Thru-Cut alternative. Table 9 illustrates the HCM Control Delay generated for the northbound approaches of the Thru-Cut alternative.

Both values were added together and transferred into the Control Delay MOE Results Table as shown in Table 10.

Key Consideration:
The Control Delay MOE Results table only allows for one input for each of the four main approaches. However, because the Thru-Cut alternative operates as a two-stage intersection, similar to existing, delays experienced in the median have to be accounted for as well. This was done by adding the directional control delays experienced in the median to the main northbound and southbound control delays.

Table 9: Report Outputs from Synchro for the Thru-Cut Alternative

<table>
<thead>
<tr>
<th>Main Intersection</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HCM Control Delay (s)</td>
<td>14.6</td>
<td>14.2</td>
</tr>
<tr>
<td></td>
<td>HCM LOS</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Eastern Crossover</td>
<td>Approach</td>
<td>NB</td>
<td>SB</td>
</tr>
<tr>
<td></td>
<td>HCM Control Delay (s)</td>
<td>19.5</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>HCM LOS</td>
<td>C</td>
<td>B</td>
</tr>
</tbody>
</table>

Table 10: Control Delay MOE Results Table - Thru-Cut Alternative

<table>
<thead>
<tr>
<th>Control Delay MOE Results</th>
<th>Input MOE</th>
<th>Northbound Result</th>
<th>% Difference from Base Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 3</td>
<td>Thru-Cut</td>
<td>Control Delay</td>
<td>34.1</td>
</tr>
</tbody>
</table>
EXPERIENCED TRAVEL TIME
Following the selection of MOEs in the Stage 2 Input Worksheet, the iCAP tool automatically generated Experienced Travel Time (ETT) sheets for alternatives requiring ETT calculations: the MUT and RCUT. The project team populated these sheets with the flow rate for each movement, the control delays for each lane group, the distances between each intersection, and the speed limit for each roadway. For example, the HCM control delay reported from Synchro, shown in Table 11 is 17.8 seconds for the northbound approach. The project team manually populated this value into the corresponding “Delay” cell in the ETT sheet for the alternative, shown in Table 12. This step was repeated for all relevant values. Once these sheets are populated with the required inputs, the iCAP tool automatically populates the calculated ETT values into the Stage 2 Input Worksheet.

Table 11: Report Outputs from Synchro for the RCUT Scenario

<table>
<thead>
<tr>
<th>Main Intersection</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCM Control Delay (s)</td>
<td>17.8</td>
<td>18.4</td>
<td></td>
</tr>
<tr>
<td>HCM LOS</td>
<td>C</td>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

Table 12: RCUT Alternative EET Control Delay Inputs

<table>
<thead>
<tr>
<th>RCUT Control Delay</th>
<th>Movement</th>
<th>Delay</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>EBT (0)</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EBR (0)</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WBT (0)</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WBR (0)</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NBR (0)</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NBT (0)</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBR (0)</td>
<td>17.8</td>
<td>Main Intersection (0)</td>
<td></td>
</tr>
<tr>
<td>SBT (0)</td>
<td>29.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key Consideration:
Due to the spacing constraints present at the study location, the MUT and RCUT alternatives do not include a western leg U-turn movement. In the MUT alternative, drivers are required to make the U-turn movement at the median opening located at the intersection of US Route 460/US Route 360 and Route A, located approximately 3,200 feet to the west of the study intersection. Unlike the MUT alternative considered, the project team designed the RCUT alternative to operate like a partial RCUT that allowed minor street through and left-turning movements from the southbound approach only. Additionally, westbound left-turning movements were also allowed to utilize the existing median opening. As a result, there was no need for a western crossover for this alternative and the value was set to zero.
### 2.2.3 Review CMF for each potential alternative

The project team populated the Stage 2 safety weights using the SMART SCALE Round 5 Planning Level CMFs list\(^7\). The list contains appropriate CMFs for both the MUT and RCUT alternatives. However, there is no CMF listed in the SMART SCALE list, the Virginia State Preferred CMF List\(^8\), or the FHWA CMF Clearinghouse\(^9\) for the Thru-Cut alternative. After consulting with the CO-TOD safety planning team, the project team took a conservative approach and left the CMF as the default value of 1.0, which projected no reduction in the number of crashes.

### 1.7.3 Stage 2 Sketch & Cost

#### 2.3.1 Create Stage 2 sketch for each alternative

Following the completion of the operations and safety evaluation, the project team produced Stage 2 sketches for each evaluated alternative. These sketches not only depict each allowable turning movement, but also include proposed and existing pavement areas, existing property lines, and right-of-way impacts. An example of a Stage 2 sketch is shown in Figure 11. Reference Section 2.3.2 of the iCAP Manual for more information on the Stage 2 Sketch guidelines.

---

\(^7\) SMART SCALE Round 5 Planning Level CMFs. https://smartscale.org/documents/2022/round_5_cmf_list.pdf


2.3.2 Complete Stage 2 construction cost estimate for each alternative

The project team input the VJuST-C Planning Level Cost Estimate for each alternative to represent the Stage 2 cost metric. These estimates, which include the total engineering and construction costs, were generated using the VJuST-C tool.

Key Consideration:

Although the MUT and RCUT alternatives utilized existing median openings for the proposed U-turn movements, the VJUST-C tool could not be modified to exclude their construction. Therefore, it was assumed that the total engineering and construction costs would be lower than estimated. The comparative numbers can be used for purposes of Alternative Selection.

The total costs generated for the study intersection were manually input into the Stage 2 Performance Matrix, as shown in Table 13.

<table>
<thead>
<tr>
<th>Intersection Type</th>
<th>Consider?</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median U-Turn</td>
<td>Yes</td>
<td>$7,674,000</td>
</tr>
<tr>
<td>Restricted Crossing U-Turn</td>
<td>Yes</td>
<td>$7,114,000</td>
</tr>
<tr>
<td>Thru-Cut</td>
<td>Yes</td>
<td>$1,069,000</td>
</tr>
</tbody>
</table>

1.7.4 Metric Performance Ranking

2.4.1 Evaluate and rank alternatives in the iCAP Tool Stage 2 Performance Matrix

Figure 12 shows the completed Stage 2 Performance Matrix for the study intersection. Reference Section 3.5.2 of the iCAP Manual for guidance on interpreting the values included in the Stage 2 Performance Matrix.
### Stage 2 Performance Matrix

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations</th>
<th>Pedestrian</th>
<th>Safety</th>
<th>Stage 1 Cost</th>
<th>Total Score</th>
<th>Preferred Alternative and Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median U-Turn EB-WB</td>
<td>6.1</td>
<td>Yes</td>
<td>+ 1.0</td>
<td>0.70</td>
<td>0.5</td>
<td>$7,674,000 0.1 3.9</td>
</tr>
<tr>
<td>Restricted Crossing U-Turn EB-WB</td>
<td>10.3</td>
<td>Yes</td>
<td>0 0.5</td>
<td>0.45</td>
<td>1.0</td>
<td>$7,114,000 0.2 3.9</td>
</tr>
<tr>
<td>Thru-Cut</td>
<td>7.7</td>
<td>Yes</td>
<td>0 0.5</td>
<td>1.00</td>
<td>0.0</td>
<td>$1,069,000 1.0 4.5</td>
</tr>
</tbody>
</table>

**Figure 12:** Stage 2 Performance Matrix
• **MUT:**
  - The MUT alternative resulted in the least amount of delay and had a favorable safety score due to the anticipated reduction in fatal and injury crashes (0.6 crashes/year).
  - The MUT was projected to have the highest engineering and construction cost. However, the cost estimate assumed that two crossovers will need to be constructed to accommodate the U-turn movements, which isn't the case. Therefore, it is expected that the total project costs will be lower than the estimated value.

• **RCUT:**
  - The RCUT resulted in the highest control delay. Although the RCUT alternative scored the lowest in the traffic operations category, the queues and delays were still considered acceptable and an improvement compared to no-build.
  - This alternative resulted in the highest anticipated crash reduction.
  - Not expected to provide improved pedestrian accommodations. However, given the location of the study intersection and the lack of existing pedestrian activity, this alternative was not penalized for a low pedestrian metric score.
  - The RCUT was projected to have the second highest engineering and construction cost. However, the cost estimate assumed that two crossovers will need to be constructed to accommodate the U-turn movements, which isn't the case. Therefore, it is expected that the total project costs will be lower than the estimated value.

• **Thru-Cut:**
  - The Thru-Cut resulted in the second highest amount of delay.
  - Because there was no CMF available for the Thru-Cut alternative, the CMF was left as 1.0, which resulted in a worse overall safety score.
  - Not expected to provide improved pedestrian accommodations. However, given the location of the study intersection and the lack of existing pedestrian activity, this alternative was not penalized for a low pedestrian metric score.
  - The Thru-Cut is expected to have the lowest total estimated engineering and construction cost.

Due to the acceptable operational performance and the anticipated crash reductions, the project team selected the RCUT as the preferred alternative.

### 1.8 Documentation & Submittal

Following the completion of the iCAP assessment, the project team exported the iCAP Assessment Outputs, shown **Figure 13** and **Figure 14** from the tool. These documents, along with the following items, were submitted to the VDOT DTE or the assigned designee for approval:

- Memo, which documents assessment assumptions and preferred alternative
- Virginia iCAP Tool
- Virginia iCAP Applicability Form
- VJuST output
- Stage 1 and Stage 2 sketches
- VJuST-C output
- Synchro outputs
- Traffic analysis and safety data

**IIM-TOD-397** contains more information on the reporting and approval requirements for Virginia iCAP assessments.
### iCAP ASSESSMENT OUTPUT

**Evaluator Name:** John Doe

**Applicability and Project Purpose and Need**

<table>
<thead>
<tr>
<th>Locality/County</th>
<th>Nottoway County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>US 660 &amp; Route A</td>
</tr>
<tr>
<td>Is the Project Located on the APM?</td>
<td>Yes</td>
</tr>
<tr>
<td>Project Description</td>
<td>PM Peak Period</td>
</tr>
<tr>
<td>Current Year</td>
<td>2020</td>
</tr>
<tr>
<td>Design Year or Future Year</td>
<td>2040</td>
</tr>
</tbody>
</table>

The purpose of this project is to address the congestion issues, primarily on the minor road (Route 723/Old Suffolk Road) intersecting US 460. Capacity preservation and safety improvement were both identified as VTrans Mid-term Needs and Priorities at this location.

**VTrans Need**

<table>
<thead>
<tr>
<th>VTrans Need</th>
<th>Priority</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity Preservation</td>
<td>Low</td>
<td>CoDG</td>
</tr>
<tr>
<td>Congestion Mitigation</td>
<td>None</td>
<td>CoDG</td>
</tr>
<tr>
<td>Pedestrian Access</td>
<td>None</td>
<td>RN</td>
</tr>
<tr>
<td>Pedestrian Safety Improvement</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Bicycle Access</td>
<td>None</td>
<td>RN</td>
</tr>
<tr>
<td>Safety Improvement</td>
<td>Medium</td>
<td>State/District</td>
</tr>
<tr>
<td>Reliability</td>
<td>None</td>
<td>RN</td>
</tr>
<tr>
<td>IEDA (USD) Access</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Rail On-time Performance</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Transit Access</td>
<td>None</td>
<td>RN</td>
</tr>
<tr>
<td>Transit Access for Equity Emphasis Areas</td>
<td>None</td>
<td>RN</td>
</tr>
<tr>
<td>Transportation Demand Management</td>
<td>Low</td>
<td>CoDG</td>
</tr>
</tbody>
</table>

**ICAP Metric Priorities**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Priority</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Operations</td>
<td>High (3)</td>
<td>Congestion along minor road, primarily due to NE and EB through volumes; high v/t ratio</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>Low (1)</td>
<td>Due to its location off US 460 and the lack of pedestrian generators, there is little to no</td>
</tr>
<tr>
<td>Safety</td>
<td>Moderate (2)</td>
<td>Safety improvement VTrans need. 9丰 crashes recorded in the last 5 years</td>
</tr>
<tr>
<td>Cost</td>
<td>Low (1)</td>
<td>No funding limitations, 0.9 priority score</td>
</tr>
</tbody>
</table>

**Volume Data, Crash History, and Multimodal Information**

**Assessment Scenario Volume Data**

<table>
<thead>
<tr>
<th>Direction</th>
<th>Volumes (veh/day)</th>
<th>Truck %</th>
<th>Daily Pedestrian Volume</th>
<th>Daily Bicycle Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastbound</td>
<td>U-Turn / Left</td>
<td>412</td>
<td>87</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Through</td>
<td>547</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>73</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Westbound</td>
<td></td>
<td>140</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Northbound</td>
<td></td>
<td>5</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Southbound</td>
<td></td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

**Existing Multimodal Accommodations**

- Pedestrian: No existing pedestrian facilities or generators
- Bicycle: No existing bicycle facilities or generators
- Transit: No existing transit stops or other facilities

**5-Year Crash Data Summary (2015-2020)**

<table>
<thead>
<tr>
<th>Crash Category</th>
<th>From:</th>
<th>To:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash Analysis Years</td>
<td>2016</td>
<td>2020</td>
</tr>
<tr>
<td>Fatal + Injury Crashes</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Pedestrian Crashes</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Bicycle Crashes</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Figure 13: iCAP Assessment Output 1
### iCAP ASSESSMENT OUTPUT

#### Stage 1: Alternatives Screening Performance Matrix

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations Metric</th>
<th>Pedestrian Metric</th>
<th>Safety Metric</th>
<th>Stage 1 Cost Metric</th>
<th>Total Stage 1 Score</th>
<th>Selected for Stage 2 Analysis?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Condition</td>
<td>0.00</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Conventional</td>
<td>0.47</td>
<td>0.5</td>
<td>0</td>
<td>0.5</td>
<td>48</td>
<td>0.0</td>
</tr>
<tr>
<td>Median U-Turn EB-WI</td>
<td>0.50</td>
<td>1.0</td>
<td>1.0</td>
<td>20</td>
<td>5.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Partial Median U-Turn EB-WI</td>
<td>0.17</td>
<td>1.0</td>
<td>1.0</td>
<td>28</td>
<td>5.9</td>
<td>0.7</td>
</tr>
<tr>
<td>Restricted Crossing U-Turn EB-WI</td>
<td>0.35</td>
<td>0.7</td>
<td>0.5</td>
<td>20</td>
<td>5.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Thru-Cut</td>
<td>0.48</td>
<td>0.5</td>
<td>0</td>
<td>28</td>
<td>3.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Two-Way Stop Control</td>
<td>0.67</td>
<td>0.2</td>
<td>0</td>
<td>48</td>
<td>2.1</td>
<td>0.0</td>
</tr>
</tbody>
</table>

#### Stage 2: Alternatives Assessment Performance Matrix

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations Metric</th>
<th>Pedestrian Metric</th>
<th>Safety Metric</th>
<th>Stage 2 Cost Metric</th>
<th>Total Stage 2 Score</th>
<th>Preferred Alternative?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median U-Turn EB-WI</td>
<td>1.0</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>5.1</td>
<td>No: Costs assume the construction of 2 crossovers, which won’t be entirely necessary due to existing median openings. Crash reductions can be conservative.</td>
</tr>
<tr>
<td>Restricted Crossing U-Turn EB-WI</td>
<td>0.0</td>
<td>0.8</td>
<td>0.8</td>
<td>1.0</td>
<td>4.5</td>
<td>Yes: Acceptable operations and highest anticipated crash reductions. Cost estimates are lower given that median openings are</td>
</tr>
<tr>
<td>Thru-Cut</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.0</td>
<td>3.6</td>
<td>No: Lowest anticipated crash reduction. This alternative also experienced the least amount of control delay. However, it does not</td>
</tr>
</tbody>
</table>

#### Metric Weighing

**Figure 14: iCAP Assessment Output 2**
Case Study #2: US Route 234 at Route A

This example project illustrates the application of the iCAP process at an intersection on the APN that experiences congestion with long queues on both major approaches during peak hours. The study intersection is in a growing area adjacent to multiple anticipated developments and a multi-use path which prompts the need to not only improve traffic operations but also consider better accommodations for other roadway users.

The intersection in this case study is a real location, however, for the purposes of Virginia iCAP policy and tool demonstration some data and location characteristics have been modified.

2.1 Project Introduction

2.1.1 Location Overview

This case study location is in Prince William County, Virginia at the signalized intersection of Route 234 (Prince William Parkway) and Route A (Minor Street). Route 234 is a four-lane, divided urban freeway/expressway on the APN and Route A is a five-lane, divided local road to the west and a three-lane, undivided local road to the east. This intersection, shown in Figure 15, provides access to Interstate 66 in the north, Route 28 in the south, and the local street network located to the east and west of the study intersection. The existing lane designations and traffic control are shown in Figure 16.

Figure 15: Aerial of Study Intersection
2.1.2 Purpose & Need

Identifying a project purpose and need helps the project team define project priorities and determine iCAP applicability. The project team identified the following challenges at this intersection.

- **Traffic operations:** Route 234 currently experiences congestion with long queuing during both peak periods primarily due to heavy through volumes in both northbound and southbound directions.
- **Pedestrian:** Anticipated growth in the area is expected to increase pedestrian activity on the adjacent multi-use path.
- **Safety:** There were 58 total crashes recorded within the influence area of the intersection for the five years between 2016 and 2020 with 37 rear end crashes, 13 angle crashes, four sideswipe crashes, two fixed object crashes, and two other crashes. Property damage only crashes accounted for 59% of the total crashes.

Figure 16: Existing Lane Designations and Traffic Control
2.2 iCAP Applicability

The project team referenced the iCAP Tool “Applicability Flowchart” provided in Figure 1 to determine if an iCAP assessment is required.

**A.1.1  Determine if the intersection is located on the APN**

Route 234 is on the APN\(^\text{10}\); therefore proceed to step A.2.1.

**A.2.1  Determine if the project purpose and need indicate traffic control should be evaluated**

Adjustments to traffic control at the intersection should be a consideration due to existing traffic operations issues, pedestrian accommodation needs, and overall safety concerns for both major approaches; therefore, proceed to step A.3.1.

**A.3.1  Determine if issues at the location can be resolved with changes to signal timing and phasing**

Signal timing and phasing changes were projected to provide limited operational improvement given anticipated growth within the corridor and not mitigate safety issues at the intersection. After further coordination with a VDOT Signal and Freeway Operations Engineer (SFOE), the project team determined the intersection requires the full iCAP assessment and should continue to the next step: A.4.

**A.4  Complete Virginia iCAP Applicability Form**

The form generated for this case study location is shown in Figure 17.

Once the VDOT District Traffic Engineer (DTE) approved the iCAP Applicability Form, the project team scheduled a scoping meeting with VDOT and other project stakeholders.

---

\(^{10}\) VDOT Arterial Preservation Network (APN) Map. [https://vdot.maps.arcgis.com/apps/webappviewer/index.html?id=6a024b2739e44b5b8599d86aa3b2c6d7](https://vdot.maps.arcgis.com/apps/webappviewer/index.html?id=6a024b2739e44b5b8599d86aa3b2c6d7)
**VIRGINIA iCAP APPLICABILITY FORM**

Evaluator: VDOT  
Date: 8/12/2022

### PROJECT LOCATION

<table>
<thead>
<tr>
<th>Locality/County:</th>
<th>Prince William County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location:</td>
<td>Route 234 &amp; Route A</td>
</tr>
</tbody>
</table>

Is the project located on the Arterial Preservation Network (APN)?

- Yes

> If Yes, complete section A. If No, complete section B.

### A) APPLICABILITY FOR LOCATIONS ON THE APN

#### PROJECT PURPOSE AND NEED

Does the project purpose and need indicate intersection or interchange control should be evaluated?

- Yes

> If Yes, proceed to Performance Based Practical Design

> If No, a Virginia iCAP assessment is not required

#### PERFORMANCE BASED PRACTICAL DESIGN

If the existing intersection is signalized, can operational and safety issues be resolved with changes to signal phasing and timing?

- No

> If Yes, a Virginia iCAP assessment is not required

> If No, a Virginia iCAP assessment is required

### B) APPLICABILITY FOR LOCATIONS OFF THE APN

Is the intersection or interchange located on a VDOT-maintained roadway? AND

Is a signal recommended as the intersection traffic control?

- Yes to both, conduct Stage 1 Virginia iCAP assessment and warrant study per the latest version of IIM-TE-387

- If No to either, a Virginia iCAP assessment is not required

### ASSESSMENT REQUIREMENT AND APPROVAL

Document the analysis required and submit to the VDOT District Traffic Engineer or designee for approval.

**Required Assessment:** Full Virginia iCAP Assessment Required

**Reason for Exclusion:**

**Justification:**

---

Figure 17: Populated iCAP Applicability Form
2.3 Existing Needs

Complete Virginia iCAP Tool General Input Worksheet

In preparation for the scoping meeting, the project team populated the General Input Worksheet in the iCAP tool. Reference Section 3.2.2 of the iCAP Manual for guidance on completing this section.

The project team utilized the VTrans Mid-Term Needs and Priorities Map\(^{11}\) to identify any transportation needs at and in the vicinity of the study location as shown in Figure 18. This information was populated into the VTrans Needs and Priorities table included in the General Input Worksheet, shown in Table 14. In addition to the identified VTrans Needs and Priorities, the project team input the following information into the General Input Worksheet:

- **Existing and future V/C ratios**\(^{12}\)
  - Route 234 existing v/c of 0.39
  - Route 234 future v/c of 0.63
- **PSI segment and intersection ranking**\(^{13}\)
  - No PSI segments
  - Intersection ranked #93
- **PSAP data**\(^{14}\)
  - Not a PSAP corridor
  - Bicycle and pedestrian generator

---

\(^{11}\) InteractVTrans Map Explorer. https://vtrans.org/interactvtrans/map-explorer

\(^{12}\) VA Statewide Planning Data Map.

\(^{13}\) Potential Safety Improvement (PSI) Map.
https://vdot.maps.arcgis.com/apps/webappviewer/index.html?id=36c14ce72fde488fb2ce3ed44377588d

\(^{14}\) Pedestrian Safety Action Plan (PSAP) Map.
https://www.arcgis.com/apps/View/index.html?appid=ae073e60495948deaf3c4d08812dfb20
Figure 18: 2019 VTrans Prioritized Mid-Term Needs
### Table 14: Completed 2019 VTrans Mid-Term Needs and Priorities

<table>
<thead>
<tr>
<th>Related iCAP Metric</th>
<th>VTrans Need</th>
<th>Priority</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Operations</td>
<td>Capacity Preservation</td>
<td>Very High</td>
<td>CoSS/RN</td>
</tr>
<tr>
<td></td>
<td>Congestion Mitigation</td>
<td>Low</td>
<td>CoSS/RN</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>Pedestrian Access</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pedestrian Safety Improvement</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bicycle Access</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>Safety Improvement</td>
<td>Very High</td>
<td>State/District</td>
</tr>
<tr>
<td></td>
<td>Reliability</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>TDM/Transit/Other</td>
<td>IEDA (UDA) Access</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rail On-time Performance</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transit Access</td>
<td>Low</td>
<td>RN</td>
</tr>
<tr>
<td></td>
<td>Transit Access for Equity Emphasis Areas</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transportation Demand Management</td>
<td>Low</td>
<td>CoSS/RN</td>
</tr>
</tbody>
</table>

The project team also input the following information into the General Input Worksheet.

- **Existing and future V/C ratios**[^15]
  - Route 234 existing v/c of 0.39
  - Route 234 future v/c of 0.63
- **PSI segment and intersection ranking**[^16]
  - No PSI segments
  - Intersection ranked #93
- **PSAP data**[^17]
  - Not a PSAP corridor
  - Bicycle and pedestrian generator

### 2.4 Metric Weighting

Prior to the scoping meeting, the project team developed draft metric weightings to be used when ranking design alternatives. The project purpose and need, historical crash data, identified VTrans priorities, and engineering judgment (see Key Considerations below) were used to determine the draft metric weights. The metric weights developed for this project are shown in **Table 15**. For more information on metric weighting, reference **Section 3.3** of the Manual.

Table 15: Project Metric Weighting

<table>
<thead>
<tr>
<th>Metric</th>
<th>Priority</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Operations</td>
<td>High (3)</td>
<td>The study was initiated due to existing congestion along the major approaches. Capacity preservation was flagged as a VTrans very high priority at the Corridor of Statewide Significance (CoSS) and Regional Network (RN) levels.</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>Moderate (2)</td>
<td>Anticipated developments are likely to increase pedestrian and other non-roadway user activity through the multi-use path that feeds through the intersection.</td>
</tr>
<tr>
<td>Safety</td>
<td>Moderate (2)</td>
<td>58 crashes were recorded at the study location within the five-year period. Safety improvements were flagged as a VTrans very high priority at the state level and a high priority at the district level.</td>
</tr>
<tr>
<td>Cost</td>
<td>Low (1)</td>
<td>No funding limitations were identified for this project.</td>
</tr>
</tbody>
</table>

Key Considerations

The Traffic Operations category was given a higher weight than the Safety category despite the fact that capacity preservation and safety improvement both ranked “very high” VTrans priorities. This higher weighting was justified since:

- Congestion mitigation was also identified as a “low” VTrans priority.
- The score for capacity preservation was assigned at both the Corridor of Statewide Significance and Regional Network levels, making it a high-priority location.
- The study was initiated primarily due to existing congestion issues on Route 234 and not for a specific safety problem.

The project team developed draft metric weightings while completing the General Input Worksheet and presented each metric priority ranking along with justification at the scoping meeting. VDOT and other project stakeholders approved the draft metric weightings, so the project team used these weightings as they advanced the study to the iCAP analysis.

2.5 Scoping Meeting

Following the approval of the iCAP Applicability Form, the project team held a scoping meeting and discussed the project purpose and need, study limits, data requirements, metric measures of effectiveness (MOEs), and analysis tools required to perform the iCAP assessment. The discussion was consistent with guidelines included in Chapter 9 of the VDOT Traffic Operations and Safety Manual (TOSAM)\(^\text{18}\) and Section 2.2.1 of the iCAP Manual. The main outcomes from the scoping meeting are summarized below.

Study Area Limits

- The analysis should focus solely on the intersection limits of Route 234 and Route A since there are no immediately adjacent intersections also experiencing congestion. Study limits were defined as the length of the longest turn lane.

Draft Metric Weights
- The DTE and other VDOT stakeholders felt that the metric weightings aligned with the needs and priorities outlined in the General Input Worksheet and approved them for use with the iCAP tool.

Study MOEs
- **Control delay and 95th percentile queue length** were selected as the analysis MOEs. The project team collectively agreed that these were the most appropriate MOEs to evaluate performance at the study intersection for congestion problems associated with each alternative.

Analysis Tools
- The project team populated the VDOT Software Selection Tool (SST) Input Form with location information and MOE selection and noted that the intersection currently operates under undersaturated conditions.
- The VDOT Software Selection Tool (SST) results showed that Synchro is the most appropriate traffic analysis tool. Per TOSA M and given there were no capacity concerns at the study intersection, Synchro is the appropriate tool to report two MOEs: control delay and 95th percentile queue length MOEs.

Analysis Period
- The project team and VDOT staff decided that the intersection alternatives should be evaluated using 2040 traffic volumes to be consistent with the travel demand model horizon year. Prior to conducting the operations analysis, the project team agreed to conduct turning movement counts at the study intersection for use in developing future no-build traffic volumes.
- The highest traffic volumes occur during the PM peak period, so the project team proposed that the iCAP analysis only be conducted for the PM peak hour.

Data Collection
- Existing conditions data was collected in 2020. Historical crash data was obtained for the five-year period between 2016 and 2020.

### 2.6 Virginia iCAP Assessment Stage 1

The project team referenced the iCAP Tool “Stage 1 Flowchart” provided in Figure 2 to complete this phase of the assessment.

#### 2.6.1 Data Collection

**Input data into the Virginia iCAP Stage 1 Input Worksheet**

**Traffic Data**

During the scoping meeting, the project team identified and agreed to the following data collection requirements: location(s) of traffic counts, day(s) of week, time(s) of day, and travel modes (e.g., vehicles, pedestrians, and/or bicycles) to be consistent with TOSAM requirements and the Virginia iCAP process. The scoping meeting was held in late September so counts were collected in early November before the holiday season. Since congestion issues were the worst during the PM peak hour (4:45 to 5:45 pm), these traffic volumes were used as the basis of the traffic analysis and grown using historic AADTs from VDOT count books.
Future (2040) traffic volumes grown from existing turning movement counts are shown in Figure 19.

**Figure 19: Future 2040 PM Peak Hour Traffic Volumes**

*Multimodal Accommodations*

There is currently a multi-use path connecting to the southeast and northwest corners of the intersection that provides bicycle and pedestrian access along Route A. Three pedestrians were recorded during the PM peak hour and pedestrian activity is projected to increase with anticipated growth in residential developments and improved pedestrian accommodations along the corridor. There are no transit facilities within one mile of the study area, but transit needs will likely increase in correlation with anticipated growth.

The project team populated the Stage 1 Input Worksheet with the 2040 PM peak hour traffic volumes, the existing multimodal accommodations, and the crash data.

### 2.6.2 Stage 1 Operations & Safety Screening

The Stage 1 performance matrix provides a framework to screen intersection alternatives based on the following four metric weights:

- Traffic operations
- Pedestrian
- Safety
- Stage 1 cost

These metrics are reported from the Virginia Junction Screening Tool (VJuST).

**Select alternatives in VJuST**

When populating the VJuST Input Worksheet, the project team excluded several intersection designs due to right-of-way concerns with proposed developments or other distinct limitations given roadway facility types and traffic patterns. The excluded intersection types and the rationale for excluding them are presented in Table 16.
Table 16: Excluded Intersection Alternatives

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Considered?</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Turn Overpass</td>
<td>No</td>
<td>Unable to accommodate traffic patterns</td>
</tr>
<tr>
<td>Continuous Green-T</td>
<td>No</td>
<td>Not feasible for roadway facility type</td>
</tr>
<tr>
<td>Echelon</td>
<td>No</td>
<td>Unable to accommodate traffic patterns</td>
</tr>
<tr>
<td>Quadrant Roadway (SE)</td>
<td>No</td>
<td>Right-of-way restrictions identified</td>
</tr>
<tr>
<td>Quadrant Roadway (SW)</td>
<td>No</td>
<td>Right-of-way restrictions identified</td>
</tr>
<tr>
<td>Single Loop</td>
<td>No</td>
<td>Unable to accommodate traffic patterns</td>
</tr>
<tr>
<td>Split Intersection</td>
<td>No</td>
<td>Not feasible for roadway facility type</td>
</tr>
<tr>
<td>Thru-cut</td>
<td>No</td>
<td>Unable to accommodate traffic patterns</td>
</tr>
<tr>
<td>Mini Roundabouts</td>
<td>No</td>
<td>Unable to accommodate heavy vehicles</td>
</tr>
</tbody>
</table>

2.6.3 VJuST Assumptions

Key Considerations

In addition to the intersection alternatives highlighted above, the project team did not consider any interchange alternatives due to right-of-way and spacing constraints and did not consider any unsignalized intersection alternatives due to heavy volumes, the functional classification, and a speed limit of 55mph along Route 234.

The project team documented the following assumptions used when conducting the VJuST analysis:

- The analysis was conducted using 2040 PM peak hour volumes.
- All adjustment factors and the truck-to-PCE factor were set to the suggested values.
- Collected traffic data suggested a truck percentage of 2% for all approaches.
- The base number of through lanes remained the same as existing for Route 234 but there was an assumed four lanes of through traffic for Route A across all alternatives.
- The presence of turn lanes and lane sharing was altered individually for each alternative.
- The primary intersection remains signalized for all alternatives.

2.6.4 Stage 1 Sketches

Create Stage 1 sketch for potentially viable alternatives

Stage 1 sketches were produced for each viable alternative evaluated in VJuST. The purpose of the Stage 1 sketch is to identify any high-level design constraints that could deem certain alternatives unavailable. To prepare a Stage 1 sketch, reference Section 2.2.2 of the iCAP Manual for more information on the Stage 1 sketch guidelines. Sketches were created for the following alternatives:

- Conventional (Modified)
- Bowtie (EB-WB)
- Full Displaced Left Turn
- Median U-Turn (NB-SB)
- Partial Displaced Left Turn (NB-SB)
- Partial Median U-Turn (NB-SB)
- Quadrant Roadway (NE)
- Quadrant Roadway (NW)
- Restricted Crossing U-Turn (NB-SB)

For the purposes of this manual, a sample stage 1 design is only provided for the selected alternative. A full iCAP analysis should include designs for each alternative selected for consideration. Figure 20 illustrates an example of a Stage 1 sketch for the Quadrant Roadway (NW) alternative:
Figure 20: Quadrant Roadway (NW) Stage 1 Sketch
2.6.5 Metric Performance Ranking

Evaluate and rank alternatives using the Virginia iCAP Tool Stage 1 Performance Matrix

A condensed version of the completed Stage 1 Performance Matrix imported from VJuST is shown in Figure 21. Reference Section 3.4.2 of the iCAP Manual for guidance on interpreting the values included in the Stage 1 Performance Matrix.

Of the nine alternatives considered in Stage 1, the following three alternatives were selected for consideration in Stage 2. The reasons for selecting these three alternatives are also summarized.

1. Bowtie (EB-WB)
2. Partial median U-turn (NB-SB)
3. Quadrant roadway (NW)

**Bowtie (EB-WB)**
- The bowtie intersection advanced to Stage 2 due to the anticipated benefits from rerouting all left turns at the primary intersection to modified roundabouts. The alternative reduces the number of conflict points and is expected to reduce the V/C ratio at the primary intersection.
- Removing the left-turn movements at the primary intersection will also improve pedestrian access and safety by removing vehicle-pedestrian conflict points.
- The two additional roundabouts may tie into existing or anticipated developments.

**Partial Median U-Turn (NB-SB)**
- The partial median U-turn intersection advanced to Stage 2 due to the reduction in the number of total conflict points and expected V/C ratio reduction.
- Pedestrian accommodations are improved by the removal of left turn conflict points.

**Quadrant Roadway (NW)**
- The quadrant roadway intersection advanced to Stage 2 due to having the best expected V/C ratio and better pedestrian accommodations by removing the number of left turn conflict points.
- This alternative has a significantly higher cost, however, the addition of the connector road may be used to facilitate access with anticipated developments.

The remaining six alternatives were not advanced to Stage 2 for the following reasons:

**Conventional (Modified)**
- The conventional intersection works operationally, however, it provides limited potential to accommodate future developments.
- The number of conflict points were not reduced.

**Full Displaced Left Turn**
- The full displaced left turn intersection encroaches on the 100-ft buffer zone established and reduces pedestrian access.

**Median U-Turn (NB-SB)**
- The median U-turn intersection cannot accommodate the high number of mainline left turns.

**Partial Displaced Left Turn (NB-SB)**
- The partial displaced left turn intersection encroaches on the 100-ft buffer zone established and reduces pedestrian access.
Quadrant Roadway (NE)
- The quadrant roadway intersection would conflict with a proposed development when oriented in this direction.

Restricted Crossing U-Turn (NB-SB)
- The restricted crossing U-turn intersection would restrict with too many vehicles using Route A to travel eastbound/westbound and thus operationally perform poorly.

As a result of this analysis, the project team advanced the bowtie, partial median U-turn, and quadrant roadway intersection alternatives to the Stage 2 Analysis in the Stage 1 Performance Matrix and proceeded to the Stage 2: Alternatives Assessment.
### Figure 21: Stage 1 Performance Matrix

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations Metric Score</th>
<th>Pedestrian Metric Score</th>
<th>Safety Metric Score</th>
<th>Stage 1 Cost Metric Score</th>
<th>Total Score Out of 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>1.23 (Weight: 3)</td>
<td>0 (Weight: 2)</td>
<td>0 (Weight: 2)</td>
<td>48 (Weight: 1)</td>
<td>--</td>
</tr>
<tr>
<td>Bowtie EB-WB</td>
<td>1.04 (0.7)</td>
<td>+ 1.0</td>
<td>24 (0.9)</td>
<td>$$$ 0.3</td>
<td>6.2</td>
</tr>
<tr>
<td>Conventional</td>
<td>0.99 (0.9)</td>
<td>0 (0.5)</td>
<td>48 (0.0)</td>
<td>$ 1.0</td>
<td>4.7</td>
</tr>
<tr>
<td>Full Displaced Left Turn</td>
<td>0.97 (1.0)</td>
<td>- 0.0</td>
<td>40 (0.3)</td>
<td>$$$ 0.3</td>
<td>3.9</td>
</tr>
<tr>
<td>Median U-Turn NB-SB</td>
<td>1.10 (0.5)</td>
<td>+ 1.0</td>
<td>20 (1.0)</td>
<td>$$$$ 0.3</td>
<td>5.8</td>
</tr>
<tr>
<td>Partial Displaced Left Turn NB-SB</td>
<td>0.97 (1.0)</td>
<td>- 0.0</td>
<td>44 (0.1)</td>
<td>$$ 0.5</td>
<td>3.7</td>
</tr>
<tr>
<td>Partial Median U-Turn NB-SB</td>
<td>1.02 (0.8)</td>
<td>+ 1.0</td>
<td>28 (0.7)</td>
<td>$$ 0.5</td>
<td>6.3</td>
</tr>
<tr>
<td>Quadrant Roadway N-E</td>
<td>0.97 (1.0)</td>
<td>0 (0.5)</td>
<td>40 (0.3)</td>
<td>$$$$ 0.3</td>
<td>4.9</td>
</tr>
<tr>
<td>Quadrant Roadway N-W</td>
<td>0.97 (1.0)</td>
<td>0 (0.5)</td>
<td>40 (0.3)</td>
<td>$$$$ 0.3</td>
<td>4.9</td>
</tr>
<tr>
<td>Restricted Crossing U-Turn NB-SB</td>
<td>0.97 (1.0)</td>
<td>0 (0.5)</td>
<td>20 (1.0)</td>
<td>$$$ 0.3</td>
<td>6.3</td>
</tr>
</tbody>
</table>

**Selection for Stage 2 and Justification**

- **Bowtie EB-WB**
  - Yes: Compatible with roadway geometry and spacing requirements.
  - No: Works operationally, however, limited potential to accommodate for future developments.

- **Partial Displaced Left Turn NB-SB**
  - No: Encroaches on the 100-foot buffer zone and reduces pedestrian access.

- **Partial Median U-Turn NB-SB**
  - Yes: Provides limited rerouting of vehicles to u-turns with improved operations and pedestrian access.

- **Quadrant Roadway N-E**
  - No: Would conflict with proposed development.

- **Quadrant Roadway N-W**
  - Yes: Compatible with proposed development while providing improvement to operations.

- **Restricted Crossing U-Turn NB-SB**
  - No: Does not accommodate heavy through volumes on the minor street.
2.7 Virginia iCAP Assessment Stage 2

The project team referenced the iCAP Tool “Stage 1 Flowchart” provided in Figure 3 to complete this phase of the assessment.

2.7.1 Additional Data Collection

The project team verified that all necessary data was available to conduct a Stage 2 evaluation using Synchro per TOSAM guidelines and proceeded to the next step: 2.2 (Operations and Safety Performance Evaluation).

2.7.2 Operations & Safety Performance Evaluation

2.2.1 Perform operational analysis using appropriate tool per TOSAM

The three Stage 2 alternatives were evaluated using Synchro per the guidelines outlined in TOSAM. The project team generated HCM 6th edition reports for each alternative for use in the iCAP Stage 2 input worksheet. Prior to transferring the Synchro outputs into the input worksheet, the sheet was populated with the agreed-upon MOEs and critical approach information as defined in step 2.2.2.

2.2.2 Input results into the Virginia iCAP Tool Stage 2 Input Worksheet

The project team selected the 95th Percentile Queue Length and Control Delay MOEs and completed the critical approach inputs.

Key Considerations

Although the project was initiated due to congestion on the major approaches, the eastbound and westbound approaches along the minor street have VTrans 2021 needs and were selected as critical approaches. As a result, all four approaches were determined to be critical.

Queuing

To determine whether queues are accommodated for each approach, the project team compared the HCM 95th Percentile Queues from the Synchro reports to the existing storage length for each movement. These values, shown in Table 17 for the base condition, were input for both the base condition and each alternative. In this example, the yellow highlighted cells show the northbound left queue of 1,200 ft exceeds the 560 ft of available turn bay storage.

Table 17: Synchro Queuing Report Outputs for the Base Condition Conventional Intersection

<table>
<thead>
<tr>
<th>Lane Group</th>
<th>NBL</th>
<th>NBT</th>
<th>NBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane Group Flow (vph)</td>
<td>420</td>
<td>1872</td>
<td>120</td>
</tr>
<tr>
<td>Total Delay</td>
<td>345.1</td>
<td>70.8</td>
<td>1.7</td>
</tr>
<tr>
<td>Queue Length 95th (ft)</td>
<td>#1200</td>
<td>#1773</td>
<td>20</td>
</tr>
<tr>
<td>Internal Link Distance (ft)</td>
<td>-</td>
<td>4765</td>
<td>-</td>
</tr>
<tr>
<td>Turn Bay Length (ft)</td>
<td>560</td>
<td>-</td>
<td>560</td>
</tr>
</tbody>
</table>

# 95th percentile volume exceeds capacity, queue may be longer.
As seen in this example, the queue lengths for all other northbound movements remain well within the available turn lane storage and adjacent road segment lengths. Table 18 illustrates how to translate these queuing report outputs into the Stage 2 Input Worksheet showing the northbound approach cannot accommodate queues for at least one movement.

Table 18: 95th Percentile Queue Inputs for the Base Condition Conventional Intersection

<table>
<thead>
<tr>
<th>95th Percentile Queue Length MOE Results</th>
<th>Input MOE</th>
<th>Westbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Condition</td>
<td>Conventional</td>
<td>95th Percentile Queue Length</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

**Control Delay**
In addition to queuing information, Synchro also reports control delay. The project team populated the Stage 2 Input Worksheet control delays like those shown in Table 19, for all critical approaches.

Table 19: Synchro Control Delay Report Outputs for the Base Condition Conventional Intersection

<table>
<thead>
<tr>
<th>Movement</th>
<th>NBL</th>
<th>NBT</th>
<th>NBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay (s)</td>
<td>393.0</td>
<td>72.3</td>
<td>25.5</td>
</tr>
<tr>
<td>Level of Service</td>
<td>F</td>
<td>E</td>
<td>C</td>
</tr>
<tr>
<td>Approach Delay (s)</td>
<td></td>
<td></td>
<td>125.8</td>
</tr>
<tr>
<td>Approach LOS</td>
<td></td>
<td></td>
<td>F</td>
</tr>
</tbody>
</table>

**Experienced Travel Time**
Following the selection of MOEs in the Stage 2 Input Worksheet, the iCAP tool automatically generated Experienced Travel Time (ETT) sheets for all three alternatives. The project team populated these sheets with the flow rate for each movement, the control delays for each lane group, the distances between each intersection, and the speed limit for each roadway. For example, the HCM control delay reported from Synchro for the main intersection of the quadrant roadway alternative, shown in Table 20, is 49.6 seconds for the eastbound through movement.

Table 20: Synchro Control Delay Report Outputs for the Main Intersection of the Quadrant Roadway (NW) Alternative

<table>
<thead>
<tr>
<th>Movement</th>
<th>EBL</th>
<th>EBT</th>
<th>EBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay (s)</td>
<td>-</td>
<td>49.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Level of Service</td>
<td>-</td>
<td>D</td>
<td>A</td>
</tr>
<tr>
<td>Approach Delay (s)</td>
<td>-</td>
<td>22.3</td>
<td>-</td>
</tr>
<tr>
<td>Approach LOS</td>
<td>-</td>
<td>C</td>
<td>-</td>
</tr>
</tbody>
</table>
The project team manually populated this value into the corresponding “Delay” cell in the ETT sheet for the quadrant roadway alternative as shown in Table 21. This step was repeated for all relevant values. Once these sheets are populated with the required inputs, the iCAP tool automatically populates the calculated ETT values into the Stage 2 Input Worksheet.

Table 21: Quadrant Roadway (NW) Alternative ETT Control Delay Inputs

<table>
<thead>
<tr>
<th>Movement</th>
<th>Delay</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>EBT (0)</td>
<td>49.6</td>
<td>Main Intersection (0)</td>
</tr>
<tr>
<td>EBR (0)</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>WBT (0)</td>
<td>61.4</td>
<td></td>
</tr>
<tr>
<td>WBR (0)</td>
<td>57.5</td>
<td></td>
</tr>
<tr>
<td>NBR (0)</td>
<td>7.3</td>
<td></td>
</tr>
<tr>
<td>NBT (0)</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>SBR (0)</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>SBT (0)</td>
<td>10.9</td>
<td></td>
</tr>
</tbody>
</table>

### 2.2.3 Review CMF for each potential alternative

The iCAP tool did not automatically populate any CMFs so the project team referenced the SMART SCALE Round 5 Planning Level CMFs List\(^{19}\) to identify applicable CMFs for each alternative. The project team could not find a direct CMF to apply for any alternative after also checking the Virginia State Preferred CMF List\(^ {20}\) and FHWA CMF Clearinghouse\(^ {21}\) for direct matches.

### Key Consideration

Although no direct CMFs were identified for all three alternatives, the project team coordinated with the VDOT Highway Safety Improvement Program (HSIP) team for input before applying the following assumptions to estimate an anticipated safety benefit for each alternative.

**Bowtie (Eastbound-Westbound)**

- CMF applied: 0.70 - SMART SCALE Planning-Level CMF for Full MUT
- Justification: The main intersection resembles that of a Full MUT in that all left turns have been removed from the intersection. As part of the bowtie concept, two additional roundabouts tie into the existing unsignalized intersections along Route A and are expected to reduce the likelihood of head on collisions and crossing conflict points. Conversely, the rerouting of vehicles at Route 234 and Route A to facilitate left turns will introduce more volumes to the east and west roundabouts which may increase the frequency of crashes.

---

\(^{19}\) SMART SCALE Round 5 Planning Level CMFs List. https://smartscale.org/documents/2022/round_5_cmf_list.pdf


\(^{21}\) FHWA CMF Clearinghouse. http://www.cmfclearinghouse.org/index.cfm
Partial Median U-Turn (Northbound-Southbound)

- CMF applied: 0.91 - SMART SCALE Planning-Level CMF for Signal Retiming
- Justification: The main intersection benefits from less signal phases and conflict areas by the removal of two movements. Modeling this as a signal retiming improvement provides a conservative estimate as the alternative removes left-turn movements on Route 234, but preserves left-turn movements for vehicles on Route A.

Quadrant Roadway (Northwest)

- CMF applied: 0.70 - SMART SCALE Planning-Level CMF for Full MUT
- Justification: The main intersection resembles that of a Full MUT in that all left turns have been removed from the intersection. The quadrant roadway includes a new connector road that ties into and signalizes an existing three-legged unsignalized intersection along Route A. The other terminus of the connector road ties into a new signalized three-legged intersection along Route 234. Signalizing the existing three-legged intersection is projected to reduce the number of collisions related to unprotected turns, however, the addition of a new approach will increase the number of conflict points and potentially increase the frequency of collisions. Furthermore, a safety benefit is not expected at the terminus tying into Route 234 as an additional access point along Route 234 introduces new conflict points.

2.7.3 Stage 2 Sketch & Cost

Create Stage 2 sketch for each alternative

Following the completion of the operations and safety evaluation, the project team produced Stage 2 sketches for each evaluated alternative. These sketches depicted each allowable turning movement, existing and proposed pavement areas, existing property lines, and right-of-way impacts. For the purposes of this manual, a sample Stage 2 sketch is only provided for the selected alternative. An example of a Stage 2 sketch is shown in Figure 22. Reference Section 2.3.2 of the iCAP Manual for more information on the Stage 2 sketch guidelines.
Figure 22: Quadrant Roadway (NW) Stage 2 Sketch
2.3.2 Complete Stage 2 construction cost estimate for each alternative

The project team input the VJuST-C Planning Level Cost Estimate for each alternative to represent the Stage 2 cost metric. These estimates, which include the total engineering and construction costs, were generated using the VJuST-C tool. The total cost for each intersection alternative was manually input into the Stage 2 Performance Matrix, as shown in Table 22.

<table>
<thead>
<tr>
<th>Intersection Type</th>
<th>Consider?</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowtie</td>
<td>Yes</td>
<td>$12,557,000</td>
</tr>
<tr>
<td>Partial Median U-Turn</td>
<td>Yes</td>
<td>$12,850,000</td>
</tr>
<tr>
<td>Quadrant Roadway</td>
<td>Yes</td>
<td>$29,593,000</td>
</tr>
</tbody>
</table>

2.7.4 Metric Performance Ranking

Evaluate and rank alternatives in the iCAP Tool Stage 2 Performance Matrix

A condensed version of the completed Stage 2 Performance Matrix for the study intersection is shown in Figure 23. Reference Section 3.5.2 of the iCAP Manual for guidance on interpreting the values included in the Stage 2 Performance Matrix.

**Bowtie (Eastbound-Westbound)**
- The bowtie alternative is projected to improve delay when compared to base conditions and operate with acceptable queues on all critical approaches. The projected delay for all critical approaches is 10% higher than the delay projected for the quadrant roadway alternative.
- This alternative improves pedestrian accommodation and safety by the removal of left turn conflict points at four movements.
- This alternative had a favorable safety score due to an anticipated reduction in 1.8 fatal or injury crashes per year.
- This alternative was projected to have the lowest engineering and construction cost at $12,557,000.

**Partial Median U-Turn (Northbound-Southbound)**
- The partial median u-turn alternative is projected to improve delay when compared to base conditions and operate with acceptable queues on all critical approaches. The projected delay for all critical approaches is over twice the value projected for both other alternatives.
- This alternative improves pedestrian accommodation and safety by the removal of left turn conflict points at two movements.
- This alternative had a favorable safety score due to an anticipated reduction in 0.5 fatal or injury crashes per year.
- This alternative was projected to have the second lowest engineering and construction cost at $12,850,000.
Quadrant Roadway (Northwest)

- The quadrant roadway alternative is projected to improve delay the most when compared to base conditions and operate with acceptable queues on all critical approaches.
- This alternative improves pedestrian accommodation and safety by the removal of left turn conflict points at four movements.
- This alternative had a favorable safety score due to an anticipated reduction in 1.8 fatal or injury crashes per year.
- This alternative was projected to have the highest engineering and construction cost at $29,593,000.

The project team selected the Quadrant Roadway as the preferred alternative for providing the best improvement to traffic operations while improving safety and pedestrian accommodations at the intersection. Additionally, the connector road terminus at Route 234 can connect to anticipated developments in the north-east quadrant which remained a priority in making this alternative a robust long-term solution.
## Stage 2 Performance Matrix

### Case Study: Route 234 & Route A

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations</th>
<th>Pedestrian</th>
<th>Safety</th>
<th>Stage 1 Cost</th>
<th>Total Score</th>
<th>Preferred Alternative and Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowtie EB-WB</td>
<td>Yes 0.9</td>
<td>+ 1.0</td>
<td>0.70</td>
<td>1.0 $12,557,000</td>
<td>1.0 7.7</td>
<td>No: Improvement to safety and delay, however, the quadrant roadway better facilitates development.</td>
</tr>
<tr>
<td>Partial Median U-Turn</td>
<td>Yes 0.5</td>
<td>+ 1.0</td>
<td>0.91</td>
<td>0.3 $12,850,000</td>
<td>1.0 5.1</td>
<td>No: Lowest improvement to safety and delay.</td>
</tr>
<tr>
<td>Quadrant Roadway N-W</td>
<td>Yes 1.0</td>
<td>0 0.5</td>
<td>0.70</td>
<td>1.0 $29,593,000</td>
<td>0.4 6.4</td>
<td>Yes: Improvement to safety and delay while better preparing the location for anticipated development.</td>
</tr>
</tbody>
</table>

### Figure 23: Stage 2 Performance Matrix
2.8 Documentation & Submittal

Following the completion of the iCAP assessment, the project team exported the iCAP Assessment Outputs, provided in Figure 24 and Figure 25, from the tool. These documents, along with the following items, were submitted to the VDOT DTE or the assigned designee for approval:

- Memo, which documents assessment assumptions and preferred alternative
- Virginia iCAP Tool
- Virginia iCAP Applicability Form
- VJuST output
- Stage 1 and Stage 2 sketches
- VJuST-C output
- Synchro outputs
- Traffic analysis and safety data

Refer to IIM-TOD-397 since it contains more information on the reporting and approval requirements for Virginia iCAP assessments.
The study corridor is a regionally significant corridor which serves both commuting travelers and local travelers. Based on the long-range land use plan, more development is planned along this corridor. The need for access from the planned developments and for capacity on the mainline is significant. The purpose of this project is to identify solutions to not only relieve existing congestion, but to also provide sufficient capacity to accommodate the anticipated growth from regional use and local travelers on this major thoroughfare. The project aims at identifying and evaluating innovative intersection concepts as cost-effective alternatives to grade-separation concepts that are planned for some of the study intersections.

### Applicability and Project Purpose and Need

<table>
<thead>
<tr>
<th>Locality/County</th>
<th>Prince William County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Intersection of Route 234 and Route A</td>
</tr>
<tr>
<td>Project Description</td>
<td>iCAP v11 Sample Project</td>
</tr>
<tr>
<td>Current Year</td>
<td>2022</td>
</tr>
<tr>
<td>Design Year or Future Year</td>
<td>2040</td>
</tr>
</tbody>
</table>

### Volume Data, Crash History, and Multimodal Information

**Volume Data**

<table>
<thead>
<tr>
<th>Direction</th>
<th>Volume (veh/hr)</th>
<th>Truck %</th>
<th>Daily Pedestrian Volume</th>
<th>Daily Bicycle Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastbound</td>
<td>123</td>
<td>2.00%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Westbound</td>
<td>166</td>
<td>2.00%</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Northbound</td>
<td>420</td>
<td>2.00%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Southbound</td>
<td>60</td>
<td>2.00%</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

** Existing Multimodal Accommodations**

- **Pedestrian**: sidewalk, northbound, and westbound approaches. A multiuse path feeds into the intersection at the southeast corner.
- **Bicycle**: A multiuse path feeds into the intersection at the southeast corner.
- **Transit**: None.

### Crash Analysis Years

**Fatal + Injury Crashes**

- From: 2018
- To: 2020
- Total: 18

**Pedestrian Crashes**

- Total: 0

**Bicycle Crashes**

- Total: 0

### iCAP Metric Priorities

<table>
<thead>
<tr>
<th>Metric</th>
<th>Priority</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Operations</td>
<td>High (3)</td>
<td>Significant congestion issues with more developments planned.</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>Moderate (2)</td>
<td>Multiuse trail connection anticipated to</td>
</tr>
<tr>
<td>Safety</td>
<td>Moderate (2)</td>
<td>Intersection ranked #93 for PSI, fair number of crashes.</td>
</tr>
<tr>
<td>Cost</td>
<td>Low (1)</td>
<td>Important, but not to impede priorities of other metrics.</td>
</tr>
</tbody>
</table>

### Figure 24: iCAP Assessment Output 1
## iCAP ASSESSMENT OUTPUT

### Stage 1: Alternatives Screening Performance Matrix

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations Metric</th>
<th>Pedestrian Metric</th>
<th>Safety Metric</th>
<th>Stage 1 Cost Metric</th>
<th>Total Stage 1 Score</th>
<th>Selected for Stage 2 Analysis?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V/C Ratio</td>
<td>Score</td>
<td>Accommodation</td>
<td>Conflict Points</td>
<td>Score</td>
<td>Cost Category</td>
</tr>
<tr>
<td>Base Condition</td>
<td>1.23</td>
<td>0.00</td>
<td>0.00</td>
<td>48</td>
<td>0.00</td>
<td>$</td>
</tr>
<tr>
<td>Bowieville EB-WB</td>
<td>1.04</td>
<td>0.7</td>
<td>+</td>
<td>1.0</td>
<td>24</td>
<td>0.0</td>
</tr>
<tr>
<td>Conventional</td>
<td>0.99</td>
<td>0.9</td>
<td>0.5</td>
<td>48</td>
<td>0.00</td>
<td>$</td>
</tr>
<tr>
<td>Full Displaced Left Turn</td>
<td>0.97</td>
<td>1.0</td>
<td>+</td>
<td>1.0</td>
<td>20</td>
<td>1.0</td>
</tr>
<tr>
<td>Median U-Turn NB-SB</td>
<td>1.10</td>
<td>0.5</td>
<td>+</td>
<td>1.0</td>
<td>1.0</td>
<td>$S$</td>
</tr>
<tr>
<td>Partial Displaced Left Turn NB-SB</td>
<td>0.97</td>
<td>1.0</td>
<td>0.0</td>
<td>44</td>
<td>0.1</td>
<td>$S$</td>
</tr>
<tr>
<td>Partial Median U-Turn NB-SB</td>
<td>1.02</td>
<td>0.8</td>
<td>1.0</td>
<td>28</td>
<td>0.7</td>
<td>$S$</td>
</tr>
<tr>
<td>Quadrant Roadway N-E</td>
<td>0.97</td>
<td>1.0</td>
<td>0.5</td>
<td>40</td>
<td>0.3</td>
<td>$S$</td>
</tr>
<tr>
<td>Quadrant Roadway N-W</td>
<td>0.97</td>
<td>1.0</td>
<td>0.5</td>
<td>40</td>
<td>0.3</td>
<td>$S$</td>
</tr>
<tr>
<td>Restricted Crossing U-Turn NB-SB</td>
<td>0.97</td>
<td>1.0</td>
<td>0.5</td>
<td>20</td>
<td>1.0</td>
<td>$S$</td>
</tr>
</tbody>
</table>

### Metric Weighting

| Metric Weighting | 3 | 2 | 2 | 1 |

### Stage 2: Alternatives Assessment Performance Matrix

#### MOE 1: Control Delay (95th Percentile Queue Length)

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations Metric</th>
<th>Pedestrian Metric</th>
<th>Safety Metric</th>
<th>Stage 2 Cost Metric</th>
<th>Total Stage 2 Score</th>
<th>Preferred Alternative?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowieville EB-WB</td>
<td>0.9</td>
<td>0.9</td>
<td>1.0</td>
<td>1.80</td>
<td>1.0</td>
<td>7.7 out of 8</td>
</tr>
<tr>
<td>Partial Median U-Turn NB-SB</td>
<td>0.5</td>
<td>0.5</td>
<td>1.0</td>
<td>0.54</td>
<td>0.3</td>
<td>5.1 out of 8</td>
</tr>
<tr>
<td>Quadrant Roadway N-W</td>
<td>1.0</td>
<td>1.0</td>
<td>0.5</td>
<td>1.80</td>
<td>1.0</td>
<td>6.4 out of 8</td>
</tr>
</tbody>
</table>

### Metric Weighting

| Metric Weighting | 3 | 2 | 2 | 1 |

---

Figure 25: iCAP Assessment Output 2
Case Study #3: US Route 11 at Street A, Street B, & Street C

This example project illustrates the application of the iCAP process at a five-leg intersection that poses safety challenges for roadway users. The study intersection is in a developed area next to multiple schools, which prompts the need to consider better pedestrian and bicycle accommodations while maintaining the current intersection level of service.

*The intersection in this case study is a real location, however, for the purposes of Virginia iCAP policy and tool demonstration some data and location characteristics have been modified.*

3.1 Project Introduction

3.1.1 Location Overview

This case study location is in the City of Bristol, Virginia at the signalized intersection of Route 11 (M.L.K. Jr Boulevard, which is a truck route through Bristol), Street A (Minor Street), Street B (Minor Street), and Street C (Minor Street). Route 11 is a two-lane, undivided principal arterial to the northeast and a four-lane, divided principal arterial to the southeast. Street A is a two-lane, undivided minor arterial, Street B is a two-lane, undivided local road, and Street C is a two-lane, undivided major collector. The intersection shown in Figure 26 provides truck access through the city and connects the local street network. The existing lane designations and traffic control are shown in Figure 27.
3.1.2 Purpose & Need

Identifying a project purpose and need helps the project team define project priorities and determine iCAP applicability. The project team identified the following challenges at this intersection.

- **Traffic operations:** This signalized intersection has long yellow and all-red times because it operates as a five-leg intersection with protected phases for each approach. Reducing the number of legs at the intersection is possible given the geometry of the adjacent road network.
- **Pedestrian:** All five approaches include sidewalks and crosswalks. The intersection lacks signalized pedestrian phases and includes a skewed crosswalk on the southbound approach to account for the sharp approach angle. The intersection is adjacent to pedestrian generators such as schools, churches, public housing, and a senior center.
- **Safety:** There were five crashes recorded within 200 feet of the intersection for the five years between 2016 and 2020 with two rear end crashes, two angle crashes, and one sideswipe crash. This includes one visible injury, two nonvisible injury, and three property damage only crashes.
3.2 iCAP Applicability

The project team referenced the iCAP Tool “Applicability Flowchart” provided in Figure 1 to determine if an iCAP assessment is required.

A.1.1 Determine if the intersection is located on the APN

This intersection is not located on the APN. While an iCAP assessment is not required based on the APN applicability criteria, an iCAP assessment could still be conducted. Given the unique characteristics and overlapping needs identified at this location, it is worth considering whether the holistic alternatives assessment framework provided by Virginia iCAP process can help address the project purpose and need. Proceed to step A.2.1.

A.2.1 Determine if the project purpose and need indicate traffic control should be evaluated

Adjustments to traffic control at the intersection should be a consideration due to unnecessarily long wait times, pedestrian needs, and overall safety concerns stemming from the five-leg intersection configuration; therefore, proceed to step A.3.1.

A.3.1 Determine if issues at the location can be resolved with changes to signal timing and phasing

Signal timing and phasing changes are projected to provide limited operational improvement due to the five-leg intersection configuration. After further coordination with a VDOT Signal and Freeway Operations Engineer (SFOE), the project team determined that the operational issues could not be resolved with changes to signal timing. Proceed to the next step: A.4.

A.4 Complete Virginia iCAP Applicability Form

The form generated for this case study location is shown in Figure 28.

Once the VDOT District Traffic Engineer (DTE) approved the iCAP Applicability Form, the project team scheduled a scoping meeting with VDOT and other project stakeholders.

Please Note

If the project team follows the Virginia iCAP process verbatim, the Virginia iCAP Applicability Form shows that the project team should prepare a traffic signal warrant study per IIM-TE-387. While not required to do so per Virginia iCAP applicability criteria, the project team continues with conducting a full Virginia iCAP assessment. Doing so provides the project team with a holistic framework to assess alternatives and offers practitioners additional example considerations to refer to while conducting a Virginia iCAP assessment.

---

22 VDOT Arterial Preservation Network (APN) Map. https://vdot.maps.arcgis.com/apps/webappviewer/index.html?id=6a024b2739e44b5b8599d86aa3b2c6d7
## VIRGINIA iCAP APPLICABILITY FORM

**Evaluator:** VDOT  
**Date:** 8/12/2022

### PROJECT LOCATION

<table>
<thead>
<tr>
<th>Locality/County:</th>
<th>Bristol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location:</td>
<td>Route 11, Street A, Street B, &amp; Street C</td>
</tr>
</tbody>
</table>

Is the project located on the Arterial Preservation Network (APN)?

- If Yes, complete section A. If No, complete section B.

### A) APPLICABILITY FOR LOCATIONS ON THE APN

#### PROJECT PURPOSE AND NEED

Does the project purpose and need indicate intersection or interchange control should be evaluated?

- If Yes, proceed to Performance Based Practical Design
- If No, a Virginia iCAP assessment is not required

#### PERFORMANCE BASED PRACTICAL DESIGN

If the existing intersection is signalized, can operational and safety issues be resolved with changes to signal phasing and timing?

- If Yes, a Virginia iCAP assessment is not required
- If No, a Virginia iCAP assessment is required

### B) APPLICABILITY FOR LOCATIONS OFF THE APN

Is the intersection or interchange located on a VDOT-maintained roadway? **AND**

Is a signal recommended as the intersection traffic control?

- If Yes to both, conduct Stage 1 Virginia iCAP assessment and warrant study per the latest version of IIM-TE-387
- If No to either, a Virginia iCAP assessment is not required

### ASSESSMENT REQUIREMENT AND APPROVAL

Document the analysis required and submit to the VDOT District Traffic Engineer or designee for approval.

**Required Assessment:** Stage 1 Virginia iCAP Assessment and Warrant Study per IIM-TE-387 Required

**Reason for Exclusion:**

**Justification:**

---

Figure 28: Populated iCAP Applicability Form
3.3 Existing Needs

A.5 Complete Virginia iCAP Tool General Input Worksheet

To prepare for the scoping meeting, the project team populated the General Input Worksheet in the iCAP tool. Reference Section 3.2.2 of the iCAP Manual for guidance on completing this section.

The project team utilized the VTrans Mid-Term Needs and Priorities Map\(^{23}\) to identify any transportation needs at and in the vicinity of the study location as shown in Figure 29. This information was populated into the VTrans Needs and Priorities table included in the General Input Worksheet, shown in Table 23. In addition to the identified VTrans Needs and Priorities, the project team input the following information into the General Input Worksheet:

- **Existing and future V/C ratios\(^{24}\)**
  - Route 11 existing v/c of 0.38
  - Route 11 future v/c of 0.41
- **PSI segment and intersection ranking\(^{25}\)**
  - No PSI segments
  - Not a ranked PSI intersection
- **PSAP data\(^{26}\)**
  - Not a PSAP corridor
  - Bicycle and pedestrian generator

\(^{23}\) InteractVTrans Map Explorer. https://vtrans.org/interactivetrans/map-explorer


Figure 29: 2019 VTrans Prioritized Mid-Term Needs
Table 23: Completed 2019 VTrans Mid-Term Needs and Priorities

<table>
<thead>
<tr>
<th>Related iCAP Metric</th>
<th>VTrans Need</th>
<th>Priority</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Operations</td>
<td>Capacity Preservation</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Congestion Mitigation</td>
<td>High</td>
<td>CoSS/RN</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>Pedestrian Access</td>
<td>High</td>
<td>RN</td>
</tr>
<tr>
<td></td>
<td>Pedestrian Safety Improvement</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bicycle Access</td>
<td>Very High</td>
<td>RN</td>
</tr>
<tr>
<td>Safety</td>
<td>Safety Improvement</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reliability</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>TDM/Transit/Other</td>
<td>IEDA (UDA) Access</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rail On-time Performance</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transit Access</td>
<td>High</td>
<td>RN</td>
</tr>
<tr>
<td></td>
<td>Transit Access for Equity Emphasis Areas</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transportation Demand Management</td>
<td>High</td>
<td>CoSS/RN</td>
</tr>
</tbody>
</table>

3.4 Metric Weighting

Prior to the scoping meeting, the project team developed draft metric weightings to be used when ranking design alternatives. The project purpose and need, historical crash data, identified VTrans priorities, and engineering judgment (see Key Considerations below) were used to determine the draft metric weights. The metric weights developed for this project are shown in Table 24. For more information on metric weighting, reference Section 3.3 of the Manual.

Table 24: Project Metric Weighting

<table>
<thead>
<tr>
<th>Metric</th>
<th>Priority</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Operations</td>
<td>High (3)</td>
<td>Operationally, a non-traditional five-leg intersection performs poorly. Congestion mitigation was flagged as a VTrans low priority at the Corridor of Statewide Significance (CoSS) level and as a high priority at the Regional Network (RN) level.</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>High (3)</td>
<td>Anticipated developments, paired with school and church activity, are likely to increase pedestrian and other non-roadway user activity around this intersection. Pedestrian access was flagged as a VTrans high priority at the Regional Network (RN) level.</td>
</tr>
<tr>
<td>Safety</td>
<td>Moderate (2)</td>
<td>Five crashes were recorded at the study location in the five-year period. Safety improvements are aimed at reducing the number of conflict points at this intersection.</td>
</tr>
<tr>
<td>Cost</td>
<td>Low (1)</td>
<td>No funding limitations were identified for this project.</td>
</tr>
</tbody>
</table>

Note: CoSS = Corridor of Statewide Significance; RN = Regional Network; IEDA = Intermodal Elkhorn Development Authority; VTrans = Virginia Transportation.
The project team developed draft metric weightings while completing the General Input Worksheet and presented each metric priority ranking along with justification at the scoping meeting. The VDOT DTE and other project stakeholders approved the draft metric weightings, so the project team used these weightings as they advanced the study to the iCAP analysis.

### 3.5 Scoping Meeting

Following the approval of the iCAP Applicability Form, the project team held a scoping meeting with the VDOT DTE and other project stakeholders to discuss the project purpose and need, study limits, data requirements, metric measures of effectiveness (MOEs), and analysis tools required to perform the iCAP assessment. The discussion was consistent with guidelines included in Chapter 9 of the VDOT Traffic Operations and Safety Manual (TOSAM)²⁷ and Section 2.2.1 of the iCAP Manual. The main outcomes from the scoping meeting are summarized below.

**Study Area Limits**
- The analysis should focus solely on the intersection limits of Route 11 with Street A, Street B, and Street C since the study was initiated to assess the complications associated with the five-leg intersection. Study limits were defined as the length of the longest turn lane.

**Draft Metric Weights**
- The VDOT DTE and other project stakeholders felt that the metric weightings aligned with the needs and priorities outlined in the General Input Worksheet and approved them for use with the iCAP tool.

**Study MOEs**
- **Control delay and 95th percentile queue length** were selected as the analysis MOEs. The project team collectively agreed that these were the most appropriate MOEs to evaluate performance at the study intersection for congestion problems associated with each alternative.

---

Analysis Tools
- The project team populated the VDOT Software Selection Tool (SST) Input Form with location information and MOE selection and noted that the intersection currently operates under undersaturated conditions.
- The VDOT Software Selection Tool (SST) results showed that Synchro is the most appropriate traffic analysis tool. Per TOSAM and given there were no capacity concerns at the study intersection, Synchro is the appropriate tool to report two MOEs: control delay and 95th percentile queue length MOEs.
- For alternatives involving a roundabout, TOSAM approves the use of Sidra Intersection to document the results.

Analysis Period
- The project team and VDOT staff decided that the intersection alternatives should be evaluated using 2030 traffic volumes to be consistent with the proposed timeline for the improvements to be implemented. Prior to conducting the operations analysis, the project team agreed to conduct turning movement counts at the study intersection for use in developing future no-build traffic volumes.
- The highest traffic volumes occur during the PM peak period, so the project team, VDOT DTE, and key project stakeholders concluded that the iCAP analysis only be conducted for the PM peak hour (4:30 to 5:30 pm).

Data Collection
- Existing conditions data was collected in 2020. Historical crash data was obtained for the five-year period between 2016 and 2020.
3.6 Virginia iCAP Assessment Stage 1

The project team referenced the iCAP Tool “Stage 1 Flowchart” provided in Figure 2 to complete this phase of the assessment.

3.6.1 Data Collection

**Input data into the Virginia iCAP Stage 1 Input Worksheet**

**Traffic Data**

During the scoping meeting, the project team identified and agreed to the following data collection requirements: location(s) of traffic counts, day(s) of week, time(s) of day, and travel modes (e.g., vehicles, pedestrians, and/or bicycles) to be consistent with TOSAM requirements and the Virginia iCAP process. The scoping meeting was held in late August so counts were collected in mid-September after school was in session. As noted in Section 3.5, traffic volumes for the PM peak hour (4:30 to 5:30 pm) were used as the basis of the traffic analysis. With concurrence from the key project stakeholders, no growth rate was applied to develop future (2030) volumes. The project team found no evidence of historical growth as calculated through a linear regression analysis of historical volumes in the study area. Future (2030) traffic volumes are shown in Figure 30 under the five-leg intersection configuration.

The iCAP Manual provides guidance on analyzing five-leg intersections in Section 4.4 and notes that both VJuST and the Virginia iCAP tool are limited to intersection alternatives with up to four legs. The project team consulted with the VDOT DTE to agree upon an appropriate analysis methodology, and in this case, it was determined that only alternatives with four or fewer approaches would be analyzed. Therefore, VJuST and the Virginia iCAP tool remained effective evaluation tools for the alternatives considered. Traffic volume rerouting assumptions were performed given the anticipated closure of Street B in all alternatives and are shown in red. Vehicles originally exiting onto Street B will now exit through Route 11, and vehicles originally entering the intersection from Street B will now bypass the intersection entirely by taking advantage of adjacent routes. These rerouted traffic volumes for an equivalent four-leg intersection for use with VJuST and the Virginia iCAP tool are shown in Figure 31.
Figure 30: Future 2030 PM Peak Hour Traffic Volumes (Existing Configuration)

Figure 31: Future 2030 PM Peak Hour Traffic Volumes (Four-Leg Intersection)
Multimodal Accommodations
There are currently sidewalks along all five intersection approaches that provide pedestrian or other non-vehicular access through crosswalks at each leg. There were 23 pedestrians recorded during the PM peak hour and pedestrian activity remained consistent throughout the week due to adjacent school and church activities. The City of Bristol, Virginia Transit System offers three fixed routes within the area including a Falls/Walmart route passing directly through the intersection with the nearest bus stop 3,000 ft east along Route 11. The transit agency was contacted to discuss any potential impacts to service with each proposed alternative.

The project team populated the Stage 1 Input Worksheet with the 2030 PM peak hour traffic volumes, the existing multimodal accommodations, and the crash data.

3.6.2 Stage 1 Operations & Safety Screening
The Stage 1 performance matrix provides a framework to screen intersection alternatives based on the following four metrics:
- Traffic operations
- Pedestrian
- Safety
- Stage 1 cost

These metrics are reported from the Virginia Junction Screening Tool (VJuST).

1.2.1 Select alternatives in VJuST
When populating the VJuST Input Worksheet, the project team excluded several intersection designs due to right-of-way concerns with proposed developments or other distinct limitations given roadway facility types and traffic patterns. The excluded intersection types and the rationale for excluding them are presented in Table 25.

Table 25: Excluded Intersection Alternatives

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Considered?</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 Mini Roundabout</td>
<td>No</td>
<td>Unable to accommodate heavy vehicles</td>
</tr>
<tr>
<td>75 Mini Roundabout</td>
<td>No</td>
<td>Unable to accommodate heavy vehicles</td>
</tr>
<tr>
<td>Two-Way Stop Control</td>
<td>No</td>
<td>Unable to accommodate magnitude of traffic volumes</td>
</tr>
</tbody>
</table>

Key Considerations
In addition to the intersection alternatives highlighted above, the project team did not consider any interchange alternatives due to right-of-way and spacing constraints, low overall traffic volumes, and the functional classifications of the roadways on each approach. The project team considered multiple configurations of the conventional intersection but did not consider any other signalized intersection alternatives due to magnitude of traffic volumes, right-of-way constraints, and spacing limitations.
3.6.3 VJuST Assumptions

The project team documented the following assumptions used when conducting the VJuST analysis:

- The analysis was conducted using 2030 PM peak hour traffic volumes rerouted under the agreed upon assumptions documented in the traffic data section of step 1.1.1.
- All adjustment factors and the truck-to-PCE factor were set to the recommended values.
- Collected traffic data suggested a truck percentage of 2% for the eastbound approach, 1% for the westbound approach, and no trucks on the other approaches.
- The presence of turn lanes and lane sharing was altered for each alternative depending on the allowable movements.
- Synchro was used to compute the v/c ratio on each approach for the conventional alternative.
- A separate traffic volume rerouting assumption was applied when analyzing the three-leg alternative.

3.6.4 Stage 1 Sketches

Stage 1 sketches were produced for each viable alternative evaluated in VJuST. The purpose of the Stage 1 sketch is to identify any high-level design constraints that could deem certain alternatives unviable. To prepare a Stage 1 sketch, reference Section 2.2.2 of the iCAP Manual for more information on the Stage 1 sketch guidelines. Sketches were created for the following alternatives:

- Signalized Four-Leg Conventional Intersection (including closure of Street B)
- Unsignalized Four-Leg Roundabout (including closure of Street B)
- Signalized Three-Leg Conventional Intersection (including closure of Street A and Street B)

For the purposes of this manual, a sample stage 1 design is only provided for the selected alternative. A full iCAP analysis should include designs for each alternative selected for consideration. Figure 32 illustrates an example of a Stage 1 sketch for the Four-Leg Roundabout alternative.
CASE STUDY #2:
TRUCK ROUTE 11, STREET A, STREET B, & STREET C

ROUNDABOUT STAGE 1 SKETCH

LEGEND:
CURB EXTENTS
EXISTING RIGHT-OF-WAY
PAVEMENT REMOVAL
CONCRETE MEDIAN

Figure 32: Four-Leg Roundabout Stage 1 Sketch
3.6.5 Metric Performance Ranking

Evaluate and rank alternatives using the Virginia iCAP Tool Stage 1 Performance Matrix

A condensed version of the completed Stage 1 Performance Matrix imported from VJuST is shown in Figure 33. Reference Section 3.4.2 of the iCAP Manual for guidance on interpreting the values included in the Stage 1 Performance Matrix.

Of the three alternatives considered in Stage 1, the following two alternatives were selected for consideration in Stage 2. The reasons for selecting these two alternatives are also summarized.

1. Unsignalized Four-Leg Roundabout (Closure of Street B)
2. Signalized Three-Leg Conventional Intersection (Closure of Street A and Street B)

Unsignalized Four-Leg Roundabout (Closure of Street B)
- The unsignalized four-leg roundabout intersection advanced to Stage 2 due to the operational benefits, lowest number of conflict points, and reduction in the possibility for head-on or right-angle collisions.
- Pedestrian accommodations are improved with the closure of one crossing, lowest number of conflict points, and lower vehicle speeds through the roundabout.

Signalized Three-Leg Conventional Intersection (Closure of Street A and Street B)
- The signalized three-leg conventional intersection advanced to Stage 2 due to the reduction of both the number of total conflict points and number of movements with low traffic volumes that can be rerouted.
- Pedestrian accommodations are improved by the reduction in total crossings.

The third alternative was not advanced to Stage 2 for the following reasons:

Signalized Four-Leg Conventional Intersection (Closure of Street B)
- The signalized four-leg conventional intersection works operationally, however, the acute angle between Street A and Street C presents operational and safety challenges.
- The number of conflict points are high compared to the other two alternatives.

As a result of this analysis, the project team advanced the unsignalized four-leg roundabout and signalized three-leg conventional intersection alternatives to the Stage 2 Analysis in the Stage 1 Performance Matrix and proceeded to the Stage 2: Alternatives Assessment.
## Case Study: Truck Route 11 & Street A, B, C

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations Metric Score</th>
<th>Pedestrian Metric Score</th>
<th>Safety Metric Score</th>
<th>Stage 1 Cost Metric Score</th>
<th>Total Score</th>
<th>Selection for Stage 2 and Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional (Five-Leg)</td>
<td>0.28</td>
<td>0</td>
<td>0</td>
<td>115</td>
<td>--</td>
<td>No: Poorest operations and highest number of conflict points.</td>
</tr>
<tr>
<td>Conventional (Four-Leg)</td>
<td>0.28</td>
<td>0</td>
<td>0.5</td>
<td>48</td>
<td>0.6</td>
<td>$5 1.0 3.7 No: Poorest operations and highest number of conflict points.</td>
</tr>
<tr>
<td>Roundabout (Four-Leg)</td>
<td>0.27</td>
<td>0.5</td>
<td>0.5</td>
<td>8</td>
<td>1.0</td>
<td>$5$ 0.7 5.7 Yes: Compatible with roadway geometry and spacing requirements while reducing the number of conflict points.</td>
</tr>
<tr>
<td>Conventional (Three-Leg)</td>
<td>0.26</td>
<td>1.0</td>
<td>0.5</td>
<td>12</td>
<td>1.0</td>
<td>$5$ 0.7 7.2 Yes: Compatible with roadway geometry and spacing requirements while reducing the number of conflict points.</td>
</tr>
</tbody>
</table>

**Figure 33: Stage 1 Performance Matrix**

### Please Note

If the project team follows the iCAP process verbatim, the iCAP Applicability Form shows that the project team should prepare a traffic signal warrant study per IIM-TE-387. Read literally, a Stage 2 Assessment would not be required for this project. However, the Stage 2 assessment is provided in this example pilot project to demonstrate how the full iCAP process can provide a holistic assessment of alternatives and offer practitioners additional example considerations to refer to while conducting an iCAP assessment.

If this example pilot project was located on the Arterial Preservations Network, a Stage 2 assessment would be required.
3.7 Virginia iCAP Assessment Stage 2

The project team referenced the iCAP Tool “Stage 1 Flowchart” provided in Figure 3 to complete this phase of the assessment.

3.7.1 Additional Data Collection

The project team verified that all necessary data was available to conduct a Stage 2 evaluation using Synchro and Sidra Intersection per TOSAM guidelines and proceeded to the next step: 2.2 (Operations and Safety Performance Evaluation).

3.7.2 Operations & Safety Performance Evaluation

The two Stage 2 alternatives were evaluated using traffic analysis software per the guidelines outlined in TOSAM. The project team generated HCM 6th edition reports for each alternative for use in the iCAP Stage 2 input worksheet. Prior to transferring the outputs into the input worksheet, the sheet was populated with the agreed-upon MOEs and critical approach information as defined in step 2.2.2.

2.2.2 Input results into the Virginia iCAP Tool Stage 2 Input Worksheet

The project team selected the 95th Percentile Queue Length and Control Delay MOEs and completed the critical approach inputs.

Key Considerations

All four approaches were determined to be critical. The northbound and eastbound approaches are on a corridor of statewide significance, the westbound approach was identified as a VTrans 2021 need, and the southbound has the highest approach traffic volume at the intersection.

Queuing

To determine whether queues are accommodated for each approach, the project team compared the HCM 95th Percentile Queues from the Synchro reports to the existing storage length for each movement and available distance to any upstream traffic signals. These values, shown in Table 26 for the signalized three-leg alternative, were input for the base condition and each alternative. In this example, the yellow highlighted cells show the southbound left queue of 55 ft is within the 375 ft of available turn bay storage and the southbound through queue of 26 ft does not queue to the upstream intersection, which is 593 ft away.

Table 26: Synchro Queuing Report Outputs for the Signalized Three-Leg Conventional Intersection

<table>
<thead>
<tr>
<th>Lane Group</th>
<th>WBL</th>
<th>WBR</th>
<th>NBT</th>
<th>SBL</th>
<th>SBT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane Group Flow (vph)</td>
<td>10</td>
<td>320</td>
<td>79</td>
<td>254</td>
<td>111</td>
</tr>
<tr>
<td>Total Delay</td>
<td>17.7</td>
<td>2.4</td>
<td>12.6</td>
<td>5.6</td>
<td>4.3</td>
</tr>
<tr>
<td>Queue Length 95th (ft)</td>
<td>13</td>
<td>32</td>
<td>40</td>
<td>55</td>
<td>26</td>
</tr>
<tr>
<td>Internal Link Distance (ft)</td>
<td>752</td>
<td>-</td>
<td>805</td>
<td>-</td>
<td>593</td>
</tr>
<tr>
<td>Turn Bay Length (ft)</td>
<td>150</td>
<td>-</td>
<td>-</td>
<td>375</td>
<td>-</td>
</tr>
</tbody>
</table>

As seen in this example, the queue lengths for all movements remain well within the available turn lane storage and adjacent road segment lengths. Table 27 illustrates how to translate the queuing report.
outputs from Synchro into the Stage 2 Input Worksheet for the southbound approach. In this case, the Stage 2 Input Worksheet shows that all queues can be accommodated because the left- and right-turn lanes have 95th Percentile Queue lengths less than the turn bay and link distance.

Table 27: 95th Percentile Queue Inputs for the Signalized Three-Leg Conventional Intersection

<table>
<thead>
<tr>
<th>Base Condition</th>
<th>No. of Approaches</th>
<th>Southbound</th>
<th>Input MOE</th>
<th>95th Percentile Queue Length MOE Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Delay</td>
<td>1</td>
<td></td>
<td>Conventional</td>
<td>95th Percentile Queue Length</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Queens Accommodated</td>
<td>Total Amount</td>
<td>Queues Acceptable?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**CONTROL DELAY**
In addition to queuing information, Synchro also reports control delay. The project team populated the Stage 2 Input Worksheet control delays, like those shown in Table 28, for all critical approaches.

Table 28: Synchro Control Delay Report Outputs for the Signalized Three-Leg Conventional Intersection

<table>
<thead>
<tr>
<th>Movement</th>
<th>WBL</th>
<th>WBR</th>
<th>NBT</th>
<th>SBL</th>
<th>SBT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay (s)</td>
<td>17.4</td>
<td>8.8</td>
<td>12.3</td>
<td>5.7</td>
<td>4.2</td>
</tr>
<tr>
<td>Level of Service</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Approach Delay (s)</td>
<td>9.0</td>
<td>12.3</td>
<td>5.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approach LOS</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Please Note**
For the roundabout alternative, TOSAM guidelines require the use of Sidra Intersection to generate the same queuing and control delay information.
2.2.3 Review CMF for each potential alternative

The iCAP tool did not automatically populate any CMFs so the project team referenced the SMART SCALE Round 5 Planning Level CMFs List\(^{28}\) to identify applicable CMFs for each alternative. The project team identified a direct CMF to apply when converting a traffic signal to roundabout but could not find a direct CMF to apply for the second alternative after also checking the Virginia State Preferred CMF List\(^ {29}\) and FHWA CMF Clearinghouse \(^{30}\) for any direct matches.

Key Considerations

Although no direct CMFs were identified for the second alternative given its unique geometric configuration, the project team coordinated with the VDOT Highway Safety Improvement Program (HSIP) team for input. It was agreed that by closing two intersection approaches at the five-leg intersection, the reduction in conflict points and sharp turns suggest there would be a safety improvement. When evaluating this alternative, the low safety weighting should not rule out its selection.

Unsignalized Four-Leg Roundabout (Closure of Street B)

- CMF applied: 0.40 - SMART SCALE Planning-Level CMF for converting traffic signal to roundabout
- Justification: This CMF applies since the intersection is currently signalized and will be converted to a roundabout. The closure of one leg makes this a conservative prediction.

Signalized Three-Leg Conventional Intersection (Closure of Street A and Street B)

- CMF applied: 1.00 – Default value consistent with iCAP Manual guidance
- Justification: By removing two intersection approaches, the primary benefits are fewer traffic signal phases and conflict points; however, there is not a directly applicable CMF for this type of improvement. No improvement was entered in the tool; however, engineering judgment suggests the reduction in the number of conflict points, driver decisions, and sharp turns would reduce the number of crashes.

3.7.3 Stage 2 Sketch & Cost

2.3.1 Create Stage 2 sketch for each alternative

Following the completion of the operations and safety evaluation, the project team produced Stage 2 sketches for each evaluated alternative. These sketches depicted allowable turning movements, existing and proposed pavement areas, existing property lines, and right-of-way impacts. For the purposes of this manual, a sample Stage 2 sketch is only provided for the selected alternative, as shown in Figure 34. Reference Section 2.3.2 of the iCAP Manual for more information on the Stage 2 sketch guidelines.

---

\(^{28}\) SMART SCALE Round 5 Planning Level CMFs List. https://smartscale.org/documents/2022/round_5_cmf_list.pdf


\(^{30}\) FHWA CMF Clearinghouse. http://www.cmfclearinghouse.org/index.cfm
CASE STUDY #2:
TRUCK ROUTE 11, STREET A, STREET B, & STREET C

ROUNDABOUT STAGE 2 SKETCH

LEGEND:
CURB EXTENTS
EXISTING RIGHT-OF-WAY
PROPOSED RIGHT-OF-WAY
PAVEMENT REMOVAL
PROPOSED CONCRETE
EXISTING CONCRETE
TRUCK APRON

Figure 34: Four-Leg Roundabout Stage 2 Sketch
2.3.2 Complete Stage 2 construction cost estimate for each alternative

The project team input the VJuST-C Planning Level Cost Estimate for each alternative to represent the Stage 2 cost metric. These estimates, including preliminary engineering and construction costs, were developed using the VJuST-C tool. The total cost for each intersection alternative was manually input into the Stage 2 Performance Matrix, as shown in Table 29.

<table>
<thead>
<tr>
<th>Intersection Type</th>
<th>Consider</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundabout (Four-Leg)</td>
<td>Yes</td>
<td>$3,403,000</td>
</tr>
<tr>
<td>Conventional (Three-Leg)</td>
<td>Yes</td>
<td>$2,155,000</td>
</tr>
</tbody>
</table>

3.7.4 Metric Performance Ranking

2.4.1 Evaluate and rank alternatives in the iCAP Tool Stage 2 Performance Matrix

A condensed version of the completed Stage 2 Performance Matrix for the study intersection is shown in Figure 35. Reference Section 3.5.2 of the iCAP Manual for guidance on interpreting the values included in the Stage 2 Performance Matrix.

Unsignalized Four-Leg Roundabout (Closure of Street B)
- The four-leg roundabout alternative is projected to improve delay when compared to base conditions and operate with acceptable queues on all approaches. The projected delay for all critical approaches is 83% lower than the delay in the existing conditions.
- This alternative improves pedestrian accommodation and safety by the removal of one crossing, fewer conflict points, and lower speeds.
- This alternative had a favorable safety score due to a reduction in 0.4 fatal or severe injury crashes per year.
- This alternative was projected to have the highest engineering and construction cost of approximately $3,400,000.

Signalized Three-Leg Conventional Intersection (Closure of Street A and Street B)
- The signalized three-leg conventional intersection alternative is projected to improve intersection delay when compared to base conditions and operate with acceptable queues on all approaches. The projected delay for all critical approaches is 46% lower than the delay in the existing conditions.
- This alternative improves pedestrian accommodation and safety by the removal of two crossings and the lowest number of conflict points.
- This alternative had a favorable safety score due to a reduction in 0.3 fatal or injury crashes per year.
- This alternative was projected to have the lowest engineering and construction cost of approximately $2,200,000.

The project team selected the roundabout as the preferred alternative since it provides the best improvement to traffic operations while preserving four legs of the intersection. This alternative significantly improves driver safety and pedestrian accommodations at the intersection.
### Figure 35: Stage 2 Performance Matrix

**Case Study:** Truck Route 11 & Street A,B,C

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations</th>
<th>Pedestrian Accommodation</th>
<th>Safety</th>
<th>Stage 1 Cost</th>
<th>Total Score</th>
<th>Preferred Alternative and Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundabout (Four-Leg)</td>
<td>5.1</td>
<td>1.0</td>
<td>0.5</td>
<td>0.40</td>
<td>1.0</td>
<td>$3,403,000 0.6 7.1 Yes: Anticipated improvement to safety and traffic operations while better preparing the location for future growth.</td>
</tr>
<tr>
<td>Conventional (Three-Leg)</td>
<td>9.8</td>
<td>0.5</td>
<td>0.5</td>
<td>1.00</td>
<td>0.0</td>
<td>$2,155,000 1.0 4.0 No: Some improvement to safety and traffic operations but provides less access through closure of two legs.</td>
</tr>
</tbody>
</table>

*Control Delay, Queue Acceptable, Traffic Operations Metric Score, Pedestrian Accommodation, SMART SCALE F+I CMF, Safety Metric Score, Stage 2 Cost Metric Score, Total Estimated Cost, Stage 2 Cost Metric Score.*
3.8 Documentation & Submittal

Following the completion of the iCAP assessment, the project team exported the iCAP Assessment Outputs, provided in Figure 36 and Figure 37, from the tool. These documents, along with the following items, were submitted to the VDOT DTE or the assigned designee for approval:

- Memo, which documents assessment assumptions and preferred alternative
- Virginia iCAP Tool
- Virginia iCAP Applicability Form
- VJuST output
- Stage 1 and Stage 2 sketches
- VJuST-C output
- Synchro outputs
- Sidra Intersection outputs
- Traffic analysis and safety data

Refer to IIM-TOD-397 since it contains more information on the reporting and approval requirements for Virginia iCAP assessments.

Please Note

The full Stage 2 assessment was included for demonstration purpose and for other reasons as mentioned in previous “Please Note” boxes.

If the project team were to follow the results from the iCAP Applicability Form literally, the team would provide documentation up until the Stage 1 sketch and any documentation as required by IIM-TE-387.
### iCAP ASSESSMENT OUTPUT

**Evaluator Name:** VDOT  
**Evaluation Date:** 8/3/2022

#### Applicability and Project Purpose and Need

<table>
<thead>
<tr>
<th>Locality/County</th>
<th>Bristol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Int. of Route 11, Street A, Street B, and Street C</td>
</tr>
<tr>
<td>Project Description</td>
<td>iCAP v11 Sample Project</td>
</tr>
<tr>
<td>Current Year</td>
<td>2022</td>
</tr>
<tr>
<td>Design Year or Future Year</td>
<td>2030</td>
</tr>
</tbody>
</table>

**Project Purpose and Need**

The study intersection is an unconventional 5-leg node that serves both commuting travelers and local travelers. Based on the long-range land use plan for this area, more development is planned along this corridor. The purpose of this project is to identify solutions to relieve congestion and provide sufficient capacity to accommodate the anticipated growth. The project aims at identifying and evaluating alternative intersection concepts that may close one or two legs in an effort to streamline flow and prevent an unnecessary amount of conflict points.

#### Volume Data, Crash History, and Multimodal Information

**5-Year Crash Data Summary (2016-2020)**

<table>
<thead>
<tr>
<th>Crash Analysis Years</th>
<th>From</th>
<th>2016</th>
<th>To</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal + Injury Crashes</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pedestrian Crashes</td>
<td>0</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Bicycle Crashes</td>
<td>0</td>
<td></td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

**Assessment Scenario Volume Data**

<table>
<thead>
<tr>
<th>Direction</th>
<th>Volume (veh/hr)</th>
<th>Truck %</th>
<th>Daily Pedestrian Volume</th>
<th>Daily Bicycle Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastbound</td>
<td>71</td>
<td>0</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Westbound</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Northbound</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Southbound</td>
<td>238</td>
<td>0</td>
<td>8</td>
<td>0</td>
</tr>
</tbody>
</table>

**Existing Multimodal Accommodations**

- Pedestrian: Unprotected pedestrian crosswalks at all approaches.
- Bicycle: None.
- Transit: None.

**iCAP Metric Priorities**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Priority</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Operations</td>
<td>High (3)</td>
<td>Poor operations given the five-leg intersection configuration.</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>High (3)</td>
<td>Considerable school and church activity within the area.</td>
</tr>
<tr>
<td>Safety</td>
<td>Moderate (2)</td>
<td>Improvements aimed to reduce number of conflict points.</td>
</tr>
<tr>
<td>Cost</td>
<td>Low (1)</td>
<td>A specific funding limitation was not identified for this project.</td>
</tr>
</tbody>
</table>

**Crash Analysis Years**

- From 2016 to 2020

---

**Figure 36: iCAP Assessment Output 1**
### iCAP ASSESSMENT OUTPUT

#### Stage 1: Alternatives Screening Performance Matrix

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations Metric</th>
<th>Pedestrian Metric</th>
<th>Safety Metric</th>
<th>Stage 1 Cost Metric</th>
<th>Total Stage 1 Score</th>
<th>Selected for Stage 2 Analysis?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Condition</td>
<td>0.28</td>
<td>0.00</td>
<td>115</td>
<td>0</td>
<td>$</td>
<td>-</td>
</tr>
<tr>
<td>Conventional</td>
<td>0.28</td>
<td>0.0</td>
<td>0</td>
<td>48</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Roundabout</td>
<td>0.27</td>
<td>0.5</td>
<td>0</td>
<td>8</td>
<td>1.0</td>
<td>$$$</td>
</tr>
<tr>
<td>Conventional</td>
<td>0.26</td>
<td>1.0</td>
<td>0</td>
<td>12</td>
<td>1.0</td>
<td>$$$</td>
</tr>
</tbody>
</table>

**Metric Weighting:**

<table>
<thead>
<tr>
<th>Pedestrian</th>
<th>Traffic Operations</th>
<th>Safety</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Stage 2: Alternatives Assessment Performance Matrix

**MOE 1:** Control Delay  
**MOE 2:** 95th Percentile Queue Length

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations Metric</th>
<th>Pedestrian Metric</th>
<th>Safety Metric</th>
<th>Stage 2 Cost Metric</th>
<th>Total Stage 2 Score</th>
<th>Preferred Alternative?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundabout</td>
<td>1.0</td>
<td>1.0</td>
<td>0.5</td>
<td>0.36</td>
<td>1.0</td>
<td>$3,403,000</td>
</tr>
<tr>
<td>Conventional</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.00</td>
<td>0.0</td>
<td>$2,155,000</td>
</tr>
</tbody>
</table>

**Metric Weighting:**

<table>
<thead>
<tr>
<th>Pedestrian</th>
<th>Traffic Operations</th>
<th>Safety</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

---

**Figure 37: iCAP Assessment Output 2**
Case Study #4: US Route 1 at Route A & Route B

This example project illustrates the application of the iCAP process at two closely spaced intersections located along an APN corridor. The study area experiences high traffic volumes in both the AM and PM peak periods due to its location near the I-95 corridor.

The intersection in this case study is a real location, however, for the purposes of Virginia iCAP policy and tool demonstration some data and location characteristics have been modified.

4.1 Project Introduction

4.1.1 Location Overview

This case study location is in Stafford County, Virginia at the intersection of US Route 1 and Route A and the intersection of US Route 1 and Route B. US Route 1 is a six-lane, divided, urban principal arterial on the APN. Route A is a two-lane, undivided, major collector that provides access to and from I-95. Route B is a two-lane, undivided, major collector that provides access to a major commercial area, as well as Route 17. This study area is shown in Figure 38. The existing lane designations and traffic control for both intersections are shown in Figure 39.
4.1.2 Purpose & Need
Identifying a project’s purpose and need helps the project team define project priorities and determine iCAP applicability. The project team identified the following concerns:

- **Congestion:** Both the Route 1/Route A and the Route 1/Route B intersections operate at LOS D during the existing PM peak period, with some movements operating at LOS E or worse.
- **Safety:** There were 29 total crashes recorded at the study intersections between 2016 and 2020. Nearly 50% of the total crashes were rear end crashes, which may be due to the queue spillback in the southbound direction.
• **Accessibility:** There are two bus stops along Route 1 south of the Route 1/Route B intersection, but no existing pedestrian or bicyclist accommodations in the study location to facilitate access to these stops.

### 4.2 iCAP Applicability

The project team referenced the iCAP Tool “Applicability Flowchart” provided in Figure 1 to determine if an iCAP assessment is required.

**Key Consideration:**

Because the project team is evaluating two intersections, two separate iCAP files were generated: one for each of the study intersections. The steps outlined in the subsequent sections were completed for both study intersections.

**A.1.1** *Determine if the intersection is located on the APN*

US Route 1 is on the APN\(^{31}\); therefore proceed to step A.2.1.

**A.2.1** *Determine if the project purpose and need indicate traffic control should be evaluated*

A change in traffic control at the study intersections should be a consideration due to existing congestion and safety issues; therefore, proceed with step A.3.1.

**A.3.1** *Determine if issues at the location can be resolved with changes to signal timing and phasing*

Due to the delay currently experienced at the intersection and the tremendous vehicular volume growth forecasted for the study location, the issues cannot be resolved with signal timing and phasing changes alone. After further coordination with a VDOT Signal and Freeway Operations Engineer (SFOE), the project team determined the intersection requires the full iCAP assessment and should continue to the next step: A.4.

**A.4** *Complete Virginia iCAP Applicability Form*

The form generated for the Route 1/Route A intersection is shown in Figure 40.

Once the VDOT District Traffic Engineer approved the iCAP Applicability Forms for both intersections, the project team scheduled a scoping meeting with VDOT and other project stakeholders.

---

\(^{31}\) VDOT Arterial Preservation Network (APN) Map
https://vdot.maps.arcgis.com/apps/webappviewer/index.html?id=6a024b2739e44b5b8599d86aa3b2c6d7
Figure 40: Populated iCAP Applicability Form
4.3 Existing Needs

**A.5 Complete Virginia iCAP Tool General Input Worksheet**

In preparation for the scoping meeting, the project team populated the General Input Worksheet in the iCAP tool. Refer to Section 3.2.2 of the iCAP Manual for guidance on completing this section.

The project team utilized the VTrans Mid-Term Needs and Priorities Map\(^{32}\) to identify any transportation needs at and in the vicinity of the study location as shown in Figure 41. This information was populated into the VTrans Needs and Priorities table included in the General Input Worksheet, shown in Table 30. In addition to the identified VTrans Needs and Priorities, the project team input the following information into the General Input Worksheet:

The project team also input the following information into the General Input Worksheet:

- **Existing and future V/C ratios**\(^{33}\)
  - Route 1 existing V/C of 0.46
  - Route 1 future V/C of 0.50
- **PSI segment and intersection ranking**\(^{34}\)
  - No PSI segments
  - Route A Intersection ranked #82
  - Route B is not ranked.
- **PSAP data**\(^{35}\)
  - Not a PSAP corridor
  - Not a bicycle and pedestrian generator

---

\(^{32}\) InteractVTrans Map Explorer. https://vtrans.org/interactvtrans/map-explorer


\(^{34}\) Potential Safety Improvement (PSI) Map. https://vdot.maps.arcgis.com/apps/webappviewer/index.html?id=36c14ce72fde488fb2ce3ed44377588d

Figure 41: 2019 VTrans Prioritized Mid-Term Needs
### 4.4 Metric Weighting

Prior to the scoping meeting, the project team developed draft metric weights to be used when ranking design alternatives. These metrics are all important to maintaining a safe and efficient highway system, however, each project has a different purpose and need. The weighting system allows analysts to compare alternatives in a way that prioritizes the specific needs of a project, while still considering and valuing each metric. The project purpose and need, the historical crash data, the identified VTrans priorities, and preliminary engineering judgment were used to determine these draft metric weights. The metric weights developed for this project are shown in Table 31. For more information on metric weighting, reference Section 3.3 of the iCAP Manual.

#### Table 31: Project Metric Weighting

<table>
<thead>
<tr>
<th>Metric Weighting</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traffic Operations</strong></td>
<td>Capacity Preservation received a high VTrans priority ranking. Several movements operate at LOS E during the PM peak. Tremendous vehicular volume growth is forecasted for the intersection.</td>
</tr>
<tr>
<td><strong>Pedestrian</strong></td>
<td>Pedestrian access was not identified as a VTrans priority, but there is no pedestrian access to existing bus stops and Transit Access was flagged as a very high VTrans Priority.</td>
</tr>
<tr>
<td><strong>Safety</strong></td>
<td>Multiple rear-end crashes occurred between Centreport Pkwy and Enon Rd. Safety Improvement received a high VTrans Priority ranking.</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>US Route 1 is classified as a corridor of statewide significance. A specific funding limitation was not identified.</td>
</tr>
</tbody>
</table>
The project team developed draft metric weights while completing the General Input Worksheet and presented each metric priority ranking along with proper justifications at the scoping meeting. VDOT and other project stakeholders approved the draft metric weights so the project team proceeded with these metric weightings in the iCAP analysis.

### 4.5 Scoping Meeting

Following the approval of the iCAP Applicability Form, the project team held a scoping meeting and discussed the project purpose and need, study limits, data requirements, MOEs, and analysis tools required to perform the iCAP assessment, per Chapter 9 of the VDOT Traffic Operations and Safety Manual (TOSAM)

36, and Section 2.2.1 of the iCAP Manual. The main outcomes from the scoping meeting are summarized below:

- **Study Area Limits:**
  - The project team and VDOT staff decided that the analysis would focus on two intersections: US Route 1 and Route A; and US Route 1 and Route B. The intersections are located approximately 1,100 feet apart and, as a result, impact each other.

- **Draft Metric Weighting:**
  - The DTE and other VDOT stakeholders felt that the metric weights aligned with the needs and priorities outlined in the General Input Worksheet, so they were approved for use with the iCAP tool.

- **Study MOEs:**
  - **Control delay** and **95th percentile queue length** were selected as the MOEs for the analysis. The group collectively agreed that these were the most appropriate MOEs to evaluate performance at the study intersection due to the congestion experienced on both northern and southern approaches.

- **Analysis Tools:**
  - The project team populated the VDOT Software Selection Tool (SST) Input Form with the location information and MOE selection and indicated that both intersections operate under undersaturated conditions.
  - The results from the VDOT SST indicated that Synchro was the most appropriate software to conduct the analysis. As per TOSAM, Synchro provides results appropriate to report the control delay and 95th percentile queue length MOEs.

---

• **Analysis Period:**
  - The project team and VDOT staff decided that the intersection alternatives would be evaluated for the 2050 horizon year in accordance with VDOT design guidance in the Road Design Manual. The project team agreed to conduct turning movement counts at the study intersections to develop future no-build volumes prior to conducting the analysis.
  - Both intersections are reported to operate worse during the PM peak period. As a result, the project team proposed conducting the iCAP analysis for the PM peak hour only.

• **Data Collection:**
  - All existing conditions data was collected in year 2021. Historic crash data was obtained for the 5-year period between 2016 and 2020.

### 4.6 Virginia iCAP Assessment Stage 1

The project team referenced the iCAP Tool “Stage 1 Flowchart” provided in Figure 2 to complete this phase of the assessment.

#### 4.6.1 Data Collection

1.1 **Input data into the Virginia iCAP Stage 1 Input Worksheet**

*Traffic Data*

Consistent with TOSAM and the Virginia iCAP process, the project team agreed upon the time periods, days, modes, and locations of count data to be taken during the scoping meeting. The scoping meeting was held in late August of 2021, so the count timeframe was decided to be early October. The project team proposed the use of historical AADT data from VDOT count books to estimate the volume growth rate used to generate 2050 volumes. The DTE and other VDOT stakeholders approved this methodology. The existing (2021) and future (2050) PM peak hour turning movement counts for the Route 1 and Route A intersection are shown in Figure 42. The existing (2021) and future (2050) PM peak hour turning movement counts for the Route 1 and Route B intersection are shown in Figure 43.

*Project-Specific Value:*

2050 traffic volumes were generated using a 2% annual growth rate, which was determined using historical count data. This baseline growth rate was then modified based on projections from FAMPO’s I-95 Corridor Study to better reflect projected traffic patterns. The generated growth rate and 2050 volumes were approved by the DTE.
Figure 42: Existing 2021 (Future 2050) PM Peak Hour Traffic Volumes (Route 1 & Route A)

Figure 43: Existing 2021 (Future 2050) PM Peak Hour Traffic Volumes (Route 1 & Route B)
Multimodal Accommodations

There are currently no bicycle or pedestrian facilities at either intersection along the Route 1 corridor. Additionally, there were no pedestrians or bicyclists present during the completion of turning movement counts. This is most likely due to the existing land use and the lack of significant pedestrian/bicycle generators along the Route 1 corridor. Although there is no existing sidewalk in the study area, there are two bus stops on the Route 1 corridor approximately 500 feet south of the Route 1 and Route B intersection. As a result, the project team and VDOT stakeholders determined that pedestrian and bicyclist needs should be considered when evaluating alternatives.

The project team populated the Stage 1 Input Worksheet with the 2050 PM peak hour traffic volumes, the existing multimodal accommodations, and the historical crash data.

4.6.2 Stage 1 Operations & Safety Screening

The Stage 1 performance matrix screens intersection alternatives based on four metrics:

- Traffic operations
- Pedestrian
- Safety
- Stage 1 cost

These metrics are reported from the Virginia Junction Screening Tool (VJuST). Because the project team is evaluating two study intersections, the project team created two separate VJuST files.

Select alternatives in VJuST

When populating the VJuST Input Worksheet, the project team excluded several intersection designs due to right-of-way concerns and general infeasibility given the roadway facility types and traffic patterns. The excluded intersection types for the Route 1/Route A intersection and the rationale for excluding them is presented in Table 32.

Table 32: Excluded Intersection Alternatives (Route 1 & Route A)

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Considered?</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowtie</td>
<td>No</td>
<td>Unable to accommodate traffic pattern</td>
</tr>
<tr>
<td>Center Turn Overpass</td>
<td>No</td>
<td>Not feasible for roadway facility type</td>
</tr>
<tr>
<td>Echelon</td>
<td>No</td>
<td>Not feasible for roadway facility type</td>
</tr>
<tr>
<td>Displaced Left Turn</td>
<td>No</td>
<td>Unable to accommodate traffic patterns</td>
</tr>
<tr>
<td>Median U-Turn</td>
<td>No</td>
<td>Unable to accommodate traffic patterns</td>
</tr>
<tr>
<td>Quadrant Roadway</td>
<td>No</td>
<td>Unable to accommodate traffic patterns</td>
</tr>
<tr>
<td>Single Loop</td>
<td>No</td>
<td>Right-of-way and spacing constraints</td>
</tr>
<tr>
<td>Split Intersection</td>
<td>No</td>
<td>Not feasible for roadway facility type</td>
</tr>
<tr>
<td>Thru-Cut</td>
<td>No</td>
<td>Unable to accommodate traffic patterns</td>
</tr>
<tr>
<td>Mini Roundabout</td>
<td>No</td>
<td>Unable to accommodate magnitude of traffic volumes</td>
</tr>
<tr>
<td>Roundabout</td>
<td>No</td>
<td>Unable to accommodate magnitude of traffic volumes</td>
</tr>
<tr>
<td>Two-Way Stop Control</td>
<td>No</td>
<td>Unable to accommodate magnitude of traffic volumes</td>
</tr>
</tbody>
</table>

The following alternatives were selected for consideration in VJuST for the Route 1/Route A intersection: Conventional, Continuous Green-T, Partial Displaced Left Turn, Partial Median U-Turn (MUT), Restricted Crossing U-Turn (RCUT), and Partial Cloverleaf.

The excluded intersection types for the Route 1/Route B intersection and the rationale for excluding them is presented in Table 33.
### Table 33: Excluded Intersection Alternatives (Route 1 & Route B)

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Considered?</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowie</td>
<td>No</td>
<td>Unable to accommodate traffic pattern</td>
</tr>
<tr>
<td>Center Turn Overpass</td>
<td>No</td>
<td>Not feasible for roadway facility type</td>
</tr>
<tr>
<td>Continuous Green-T</td>
<td>No</td>
<td>Unable to accommodate traffic pattern</td>
</tr>
<tr>
<td>Echelon</td>
<td>No</td>
<td>Not feasible for roadway facility type</td>
</tr>
<tr>
<td>Displaced Left Turn</td>
<td>No</td>
<td>Unable to accommodate traffic patterns</td>
</tr>
<tr>
<td>Median U-Turn</td>
<td>No</td>
<td>Unable to accommodate traffic patterns</td>
</tr>
<tr>
<td>Quadrant Roadway</td>
<td>No</td>
<td>Unable to accommodate traffic patterns</td>
</tr>
<tr>
<td>Single Loop</td>
<td>No</td>
<td>Right-of-way and spacing constraints</td>
</tr>
<tr>
<td>Split Intersection</td>
<td>No</td>
<td>Not feasible for roadway facility type</td>
</tr>
<tr>
<td>Thru-Cut</td>
<td>No</td>
<td>Unable to accommodate traffic patterns</td>
</tr>
<tr>
<td>Mini Roundabout</td>
<td>No</td>
<td>Unable to accommodate magnitude of traffic volumes</td>
</tr>
<tr>
<td>Roundabout</td>
<td>No</td>
<td>Unable to accommodate magnitude of traffic volumes</td>
</tr>
<tr>
<td>Two-Way Stop Control</td>
<td>No</td>
<td>Unable to accommodate magnitude of traffic volumes</td>
</tr>
</tbody>
</table>

### Key Consideration:

A previous SmartScale project evaluated the impacts of expanding the Route 1/Route B intersection by adding additional turn lanes on the northbound and eastbound approaches. The proposed alternative was funded for future implementation and was therefore considered in VJuST as a modified conventional intersection.

The following alternatives were selected for consideration in VJuST for the Route 1/Route B intersection: Conventional (Modified), Partial Displaced Left Turn, Partial Median U-Turn (MUT), and Restricted Crossing U-Turn (RCUT).

#### 4.6.3 VJuST Assumptions

The project team documented the assumptions below, for conducting the VJuST analysis. These assumptions were based on available data and discussions with the DTE during the scoping meeting.

- The analysis was conducted using available 2050 PM peak hour turning movements.
- All adjustment factors and the truck to PCE factor were set to the suggested values.
- The base number of through lanes remained the same as existing for Route 1.
- A 2% truck percentage was used for all approaches.
- The presence of turn lanes and lane sharing was altered individually for each alternative.

#### 4.6.4 Stage 1 Sketches

*Create Stage 1 sketch for potentially viable alternatives*

Stage 1 sketches were produced for each viable alternative evaluated in VJuST. The purpose of the Stage 1 sketch is to identify any high-level design constraints that could deem certain alternatives unavailable. Reference Section 2.2.2 of the iCAP Manual for more information on the Stage 1 Conceptual Layout guidelines. Sketches were created for the following Route 1/Route A intersection alternatives:

- Continuous Green-T
- Partial Displaced Left Turn NB-SB
- Partial Median U-Turn NB-SB
- Restricted Crossing U-Turn NB-SB
- Partial Cloverleaf
Sketches were also created for the following Route 1/Route B intersection alternatives:

- Conventional (Modified)
- Partial Displaced Left Turn NB-SB
- Restricted Crossing U-Turn NB-SB
- Partial Median U-Turn NB-SB

For the purposes of this manual, a sample Stage 1 sketch is only provided for the selected alternative for the Route 1/Route A intersection. A full iCAP analysis should include designs for each alternative selected for consideration. **Figure 44** illustrates an example of a Stage 1 sketch for the Partial Cloverleaf alternative. In a full iCAP analysis, the Stage 1 sketch for this alternative would have included sketches of both intersections.

![Figure 44: Partial Cloverleaf (Route 1/Route A) Stage 1 Sketch](image)

**4.6.5 Metric Performance Ranking**

> Evaluate and rank alternatives using the Virginia iCAP Tool Stage 1 Performance Matrix

Condensed versions of the completed Stage 1 Performance Matrix imported from VJuST are shown in **Figure 45** and **Figure 46**. Reference **Section 3.4.2** of the iCAP Manual for guidance on interpreting the values included in the Stage 1 Performance Matrix.
### Figure 45: Stage 1 Performance Matrix (Route 1 & Route A)

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations</th>
<th>Pedestrian</th>
<th>Safety</th>
<th>Stage 1 Cost</th>
<th>Total Score</th>
<th>Selection for Stage 2 and Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>1.08</td>
<td>--</td>
<td>0</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Continuous Green-T</td>
<td>0.77</td>
<td>0.6</td>
<td>0</td>
<td>12</td>
<td>$</td>
<td>5.8 (Yes: Resulted in a reduced v/c ratio. Reduction in overall number of conflict points.)</td>
</tr>
<tr>
<td>Partial Displaced Left Turn NB-SB</td>
<td>1.08</td>
<td>0.0</td>
<td>0</td>
<td>44</td>
<td>$$</td>
<td>1 (No: Does not improve operations or the number of conflict points. No improvement on pedestrian accommodations.)</td>
</tr>
<tr>
<td>Partial Median U-Turn NB-SB</td>
<td>1.11</td>
<td>0.0</td>
<td>+</td>
<td>28</td>
<td>$$</td>
<td>4.8 (No: Does not improve traffic operations.)</td>
</tr>
<tr>
<td>Restricted Crossing U-Turn NB-SB</td>
<td>0.90</td>
<td>0.4</td>
<td>0</td>
<td>20</td>
<td>$$</td>
<td>5.6 (Yes: Resulted in a reduced v/c ratio compared to conventional. Reduction in overall number of conflict points.)</td>
</tr>
<tr>
<td>Partial Cloverleaf</td>
<td>0.60</td>
<td>1.0</td>
<td>0</td>
<td>20</td>
<td>$$</td>
<td>7.1 (Yes: Resulted in the lowest v/c ratio. Reduction in overall number of conflict points.)</td>
</tr>
</tbody>
</table>

**STAGE 1 PERFORMANCE MATRIX**

(Table condensed for illustrative purposes)

Case Study: Route 1 & Route A
## Stage 1 Performance Matrix

(Table condensed for illustrative purposes)

### Case Study:
Route 1 & Route B

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations</th>
<th>Pedestrian</th>
<th>Safety</th>
<th>Stage 1 Cost</th>
<th>Total Score</th>
<th>Selection for Stage 2 and Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>1.43</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Partial Displaced Left Turn NB-SB</td>
<td>1.28</td>
<td>0.7</td>
<td>-</td>
<td>0.1</td>
<td>$5</td>
<td>No: Highest planning-level cost. Did not result in the best operational performance.</td>
</tr>
<tr>
<td>Partial Median U-Turn NB-SB</td>
<td>1.29</td>
<td>0.6</td>
<td>1.0</td>
<td>0.7</td>
<td>$3</td>
<td>No: Worst operational performance.</td>
</tr>
<tr>
<td>Restricted Crossing U-Turn NB-SB</td>
<td>1.23</td>
<td>0.9</td>
<td>0.5</td>
<td>20.0</td>
<td>$5</td>
<td>No: Considered by the DTE but ultimately rejected in favor of a reduced V/C ratio.</td>
</tr>
<tr>
<td>Conventional (Modified)</td>
<td>1.20</td>
<td>1.0</td>
<td>0.5</td>
<td>0.0</td>
<td>$1</td>
<td>Yes: Best operational performance and least expensive option.</td>
</tr>
</tbody>
</table>

---

Figure 46: Stage 1 Performance Matrix (Route 1 & Route B)
Of the six total alternatives initially considered for the Route 1/Route A intersection, three were selected for consideration in Stage 2: Continuous Green-T, RCUT, and Partial Cloverleaf.

- **Continuous Green-T:**
  - The Continuous Green-T alternative was moved forward due to the expected V/C ratio improvements and the reduction in the number of total conflict points at the intersection.
  - This alternative results in the lowest number of conflict points.
  - However, the Continuous Green-T is the only alternative being moved forward that provides fewer pedestrian accommodations compared to conventional.

- **RCUT:**
  - The RCUT alternative was moved forward due to the expected V/C ratio improvements and the reduction in the number of total conflict points at the intersection.

- **Partial Cloverleaf:**
  - The Partial Cloverleaf alternative was moved forward because it resulted in the lowest V/C ratio.
  - Additionally, the Partial Cloverleaf alternative results in a reduction in the number of total conflict points at the intersection.
  - The Partial Cloverleaf alternative had the highest overall planning-level cost. However, costs are expected to be lower since VJuST assumes that two loop ramps have to be constructed.

The remaining alternatives were not moved forward for the following reasons:

- **Conventional Displaced Left-Turn:**
  - This alternative was not moved forward because it was not expected to result in improved traffic operations.
  - Additionally, this alternative did not significantly reduce the number of conflict points at the intersection compared to the other alternatives.

- **Partial MUT:**
  - This alternative was not moved forward because it resulted in the highest V/C ratio.

The project team selected Continuous Green-T, RCUT, and Partial Cloverleaf for Stage 2 Analysis in the Stage 1 Performance Matrix and proceeded to the next step: 1.5 (Continue to Stage 2: Alternatives Assessment).

### Key Consideration:

The results of the Route 1/Route B Stage 1 iCAP analysis found that the modified conventional signal, which included the funded lane improvements, performed operationally better than the other alternatives. Additionally, the project team felt that the funded project should be constructed and evaluated for actual performance prior to considering any additional improvement needs. Therefore, no further analysis was conducted for the Route 1/Route B intersection and the project team moved forward with the modified conventional signal.

### 4.7 Virginia iCAP Assessment Stage 2

The project team referenced the iCAP Tool “Stage 2 Flowchart” provided in Figure 3 to complete this phase of the assessment.

#### 4.7.1 Additional Data Collection

No additional data was required so the project team proceeded to the next step: 2.2 (Operations and Safety Performance Evaluation).
4.7.2 Operations & Safety Performance Evaluation

**2.2.1 Perform operational analysis using appropriate tool per TOSAM**

The Continuous Green-T, RCUT, and Partial Cloverleaf alternatives were modeled and evaluated using Synchro and following the guidelines outlined in TOSAM. The project team generated HCM 6th edition reports for each alternative for use in the iCAP Stage 2 input worksheet. Prior to transferring the Synchro outputs into the input worksheet, the sheet was populated with the agreed-upon MOEs and the critical approach information.

**2.2.2 Input results into the Virginia iCAP Tool Stage 2 Input Worksheet**

The project team selected the 95th Percentile Queue Length and Control Delay MOEs and completed the critical approach inputs.

**Key Consideration:**

Although the minor approach experiences high amounts of delay in the PM peak period, the Route 1 corridor tends to experience even more delay. This is typically due to spillover traffic from I-95 congestion and other incidents. Additionally, the Route 1 corridor has the higher-priority VTRANS needs. As a result, the northbound and southbound approaches (Route 1) were selected as the critical approaches.

**QUEUING**

To determine whether queues are accommodated for each approach, the project team compared the HCM 95th Percentile Queues provided in the Synchro reports, like those shown in Table 34, to the length of the storage provided for the respective movement.

<table>
<thead>
<tr>
<th>Lane Group</th>
<th>SBL</th>
<th>SBT</th>
<th>SBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane Group Flow (vph)</td>
<td>154</td>
<td>2831</td>
<td>0</td>
</tr>
<tr>
<td>Total Delay</td>
<td>1.8</td>
<td>0.4</td>
<td>-</td>
</tr>
<tr>
<td>Queue Length 95th (ft)</td>
<td>8</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Internal Link Distance (ft)</td>
<td>-</td>
<td>711</td>
<td>-</td>
</tr>
<tr>
<td>Turn Bay Length (ft)</td>
<td>345</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

In this example, the queue length for the SBL movement is easily accommodated in the available storage within the turn bay. Table 35 illustrates how this information was transferred into the 95th Percentile Queue Length MOE Results table in the Stage 2 Input Worksheet.
Table 35: 95th Percentile Queue Inputs for the Partial Cloverleaf Alternative

<table>
<thead>
<tr>
<th>Alternative 2</th>
<th>Input MOE</th>
<th>Southbound # of Approaches</th>
<th>Queues Accommodated</th>
<th>Total Amount</th>
<th>Queues Acceptable?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial Cloverleaf</td>
<td>95th Percentile Queue Length</td>
<td>1</td>
<td>1</td>
<td></td>
<td>All Queues Accommodated – Justification Not Required</td>
</tr>
</tbody>
</table>

Key Consideration:
Because the RCUT alternative included a U-Turn movement at the northern crossover, the project team included an additional northbound approach to capture any queuing that may result from vehicles waiting to make the U-turn movement onto southbound Route 1.

CONTROL DELAY
In addition to queuing information, the reports generated from Synchro included information on control delay. The project team populated the Stage 2 Input Worksheet with the control delays for the base condition (Conventional), the Continuous Green-T alternative, and the Partial Cloverleaf alternative. Table 36 illustrates the HCM Control Delay generated for the southbound approach of the Partial Cloverleaf alternative.

Table 36: Synchro Control Delay Report Outputs for the Partial Cloverleaf Alternative

<table>
<thead>
<tr>
<th>Movement</th>
<th>SBL</th>
<th>SBT</th>
<th>SBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay (s)</td>
<td>393.0</td>
<td>72.3</td>
<td>25.5</td>
</tr>
<tr>
<td>Level of Service</td>
<td>F</td>
<td>E</td>
<td>C</td>
</tr>
<tr>
<td>Approach Delay (s)</td>
<td></td>
<td>125.8</td>
<td></td>
</tr>
<tr>
<td>Approach LOS</td>
<td>F</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXPERIENCED TRAVEL TIME
Following the selection of MOEs in the Stage 2 Input Worksheet, the iCAP tool automatically generated Experienced Travel Time (ETT) sheets for the alternative requiring ETT calculations: the RCUT. The project team populated these sheets with the flow rate for each movement, the control delays for each lane group, the distances between each intersection, and the speed limit for each roadway. For example, the HCM control delay reported from Synchro for the main intersection of the RCUT alternative, shown in Table 37, is 14.4 seconds for the northbound right-turn movement.
Table 37: Synchro Control Delay Report Outputs for the Main Intersection of the RCUT Alternative

<table>
<thead>
<tr>
<th>Movement</th>
<th>NBL</th>
<th>NBT</th>
<th>NBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay (s)</td>
<td>-</td>
<td>17.8</td>
<td><strong>14.4</strong></td>
</tr>
<tr>
<td>Level of Service</td>
<td>-</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Approach Delay (s)</td>
<td>-</td>
<td>16.4</td>
<td>-</td>
</tr>
<tr>
<td>Approach LOS</td>
<td>-</td>
<td>B</td>
<td>-</td>
</tr>
</tbody>
</table>

The project team manually populated this value into the corresponding “Delay” cell in the ETT sheet for the RCUT alternative as shown in Table 38. This step was repeated for all relevant values. Once these sheets are populated with the required inputs, the iCAP tool automatically populates the calculated ETT values into the Stage 2 Input Worksheet.

Table 38: RCUT Alternative ETT Control Delay Inputs (Route 1/Route A Intersection)

<table>
<thead>
<tr>
<th>Movement</th>
<th>Delay</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>EBR (0)</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>WBR (0)</td>
<td>61.9</td>
<td></td>
</tr>
<tr>
<td>NBL (0)</td>
<td>0.0</td>
<td>Main Intersection (0)</td>
</tr>
<tr>
<td>NBT (0)</td>
<td>17.8</td>
<td></td>
</tr>
<tr>
<td>NBR (0)</td>
<td><strong>14.4</strong></td>
<td></td>
</tr>
<tr>
<td>SBL (0)</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>SBT (0)</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>SBR (0)</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

Key Consideration:

Since the existing intersection only has three approaches, the RCUT alternative did not need to include a southern leg U-turn movement. As a result, the value for the distance to/from the southern crossover was set to zero.
Review CMF for each potential alternative

The project team populated the Stage 2 safety weights using the SMART SCALE Round 5 Planning Level CMFs list. The list contains appropriate CMFs for both the Continuous Green-T and RCUT alternatives. However, there is no CMF listed in the SMART SCALE list, the Virginia State Preferred CMF List, or the FHWA CMF Clearinghouse for the Partial Cloverleaf alternative.

Key Consideration:

Although no CMFs were identified specific to the Partial Cloverleaf alternative, the project team coordinated with the VDOT Highway Safety Improvement Program (HSIP) team for input before applying the following assumptions to estimate an anticipated safety benefit for each alternative.

FHWA CMF Clearinghouse for the Partial Cloverleaf alternative.

Partial Cloverleaf

- CMF applied: 0.97
- Justification: The project team estimated the projected crash reduction resulting from: the removal of the westbound left-turn movement; the conversion of the southbound through movement from signalized to free-flowing. The project team estimated a 0.35 5-year fatal and injury crash reduction, which results in 12.65 crashes in the 5-year period. This corresponds with a CMF of 0.97. It is likely that this alternative will result in additional safety benefits from the reduced congestion levels, therefore reducing the number of rear-end crashes, but this was not included in the development of this CMF because its impact is difficult to quantify.

Stage 2 Sketch & Cost

Following the completion of the operations and safety evaluation, the project team produced Stage 2 sketches for each evaluated alternative. These sketches not only depict each allowable turning movement, but also include proposed and existing pavement areas, existing property lines, and right-of-way impacts. An example of a Stage 2 sketch is shown in Figure 47. Reference Section 2.3.2 of the iCAP Manual for more information on the Stage 2 Sketch guidelines.

---

37 SMART SCALE Round 5 Planning Level CMFs. https://smartscale.org/documents/2022/round_5_cmf_list.pdf
Complete Stage 2 construction cost estimate for each alternative

The project team input the VJuST-C Planning Level Cost Estimate for each alternative to represent the Stage 2 cost metric. These estimates, which include the total engineering and construction costs, were generated using the VJuST-C tool. The total costs generated for the Route 1/Route A intersection were manually input into the Stage 2 Performance Matrix, as shown in Table 39.

Table 39: VJuST-C Results

<table>
<thead>
<tr>
<th>Intersection Type</th>
<th>Consider?</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Green-T</td>
<td>Yes</td>
<td>$2,496,000</td>
</tr>
<tr>
<td>Restricted Crossing U-Turn</td>
<td>Yes</td>
<td>$8,352,000</td>
</tr>
<tr>
<td>Partial Cloverleaf</td>
<td>Yes</td>
<td>$26,617,000</td>
</tr>
</tbody>
</table>

4.7.4 Metric Performance Ranking

Evaluate and rank alternatives in the iCAP Tool Stage 2 Performance Matrix

A condensed version of the completed Stage 2 Performance Matrix for the Route 1/Route A intersection is shown in Figure 48. Reference Section 3.5.2 of the iCAP Manual for guidance on interpreting the values included in the Stage 2 Performance Matrix.
### STAGE 2 PERFORMANCE MATRIX

(Table condensed for illustrative purposes)

**Case Study:**
Route 1 & Route A

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations</th>
<th>Pedestrian</th>
<th>Safety</th>
<th>Stage 1 Cost</th>
<th>Total Score</th>
<th>Preferred Alternative and Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contious Green-T</td>
<td>17.3</td>
<td>Yes</td>
<td>0.1</td>
<td>0.0</td>
<td>0.85</td>
<td>0.4 $2,331,000 1.0 2.5 No: Results in reduced delay and improved safety, but does not provide better pedestrian accommodations. Eliminated by DTE and VDOT staff.</td>
</tr>
<tr>
<td>Restricted Crossing U-Turn EB-WB</td>
<td>28.7</td>
<td>Yes</td>
<td>0.1</td>
<td>0</td>
<td>0.65</td>
<td>1.0 $7,414,000 0.3 4.6 No: Results in the greatest safety benefit, but performs the worst in terms of control delay - some queues were not accommodated.</td>
</tr>
<tr>
<td>Partial Cloverleaf</td>
<td>1.9</td>
<td>Yes</td>
<td>1.0</td>
<td>0</td>
<td>0.5</td>
<td>0.97 0.1 0.1 4.4 Yes: Results in the least amount of control delay. There is evidence that this alternative will also improve safety, but there was no documented CMF available - additional safety benefits are possible.</td>
</tr>
</tbody>
</table>

Figure 48: Stage 2 Performance Matrix
- **Continuous Green-T**
  - The Continuous Green-T alternative is projected to improve delay when compared to base conditions and operate with acceptable queues on all critical approaches.
  - This alternative had a favorable safety score due to an anticipated reduction of 0.4 fatal or injury crashes per year.
  - The Continuous Green-T was the only alternative expected to worsen pedestrian accommodations when compared to base conditions.
  - This alternative was projected to have the lowest engineering and construction cost at $2,331,000.
  - The Continuous Green-T alternative was removed from consideration following a discussion with the DTE. The DTE and other VDOT stakeholders were concerned that queues from the Route 1/Route B intersection would extend into the Green-T configuration. Additionally, they were concerned that there is insufficient distance for drivers to merge onto southbound Route 1 from Route A.

- **RCUT**
  - The RCUT alternative is projected to improve delay when compared to base conditions. However, this alternative results in the highest control delay for the southbound approach, which is the predominant movement in the PM peak period. Additionally, some queues are not accommodated.
  - This alternative had a favorable safety score due to an anticipated reduction of 0.9 fatal or injury crashes per year.
  - This alternative was projected to have the second lowest engineering and construction cost at $7,414,000.

- **Partial Cloverleaf**
  - The quadrant roadway alternative is projected to improve delay the most when compared to base conditions and operate with acceptable queues on all critical approaches.
  - This alternative had a favorable safety score due to an anticipated reduction of 0.1 fatal or injury crashes per year. It is possible that this alternative could result in greater safety benefits that were not quantified.
  - This alternative was projected to have the highest engineering and construction cost at $26,617,000.

The project team selected the Partial Cloverleaf as the preferred alternative for providing the best improvement to traffic operations while improving safety at the intersection.

### 4.8 Documentation & Submittal

Following the completion of the iCAP assessment, the project team exported the iCAP Assessment Outputs, shown in Figure 49 and Figure 50 from the tool. These documents, along with the following items, were submitted to the VDOT DTE or the assigned designee for approval:

- Memo, which documents assessment assumptions and preferred alternative
- Virginia iCAP Tool
- Virginia iCAP Applicability Form
- VJuST output
- Stage 1 and Stage 2 sketches
- VJuST-C output
- Synchro outputs
- Traffic analysis and safety data

**IIM-TOD-397** contains more information on the reporting and approval requirements for Virginia iCAP assessments.
### iCAP Assessment Output

#### Evaluator Name:
John Doe

### Applicability and Project Purpose and Need

<table>
<thead>
<tr>
<th>Locality/County</th>
<th>Stafford County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Fredericksburg, Virginia</td>
</tr>
<tr>
<td>Project Located on the ARTP?</td>
<td>Yes</td>
</tr>
<tr>
<td>Project Description</td>
<td>Route 1/Route A Intersection analysis</td>
</tr>
<tr>
<td>Current Year</td>
<td>2021</td>
</tr>
<tr>
<td>Design Year or Future Year</td>
<td>2050</td>
</tr>
</tbody>
</table>

**Purpose of the study:** To evaluate and develop alternatives to address the congestion and safety issues at the intersections of Route 1 and Routes A and B. Additionally, improving accessibility is a key project goal.

### VTrans Need

<table>
<thead>
<tr>
<th>VTrans Need</th>
<th>Priority</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity Preservation</td>
<td>High</td>
<td>CoGS</td>
</tr>
<tr>
<td>Congestion Mitigation</td>
<td>None</td>
<td>CoGS</td>
</tr>
<tr>
<td>Pedestrian Access</td>
<td>None</td>
<td>RN</td>
</tr>
<tr>
<td>Pedestrian Safety Improvement</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Bicycle Access</td>
<td>Medium</td>
<td>RN</td>
</tr>
<tr>
<td>Safety Improvement</td>
<td>High</td>
<td>State/District</td>
</tr>
<tr>
<td>Reliability</td>
<td>None</td>
<td>CoGS</td>
</tr>
<tr>
<td>IEDA (UDA) Access</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Rail On-time Performance</td>
<td>None</td>
<td>CoGS</td>
</tr>
<tr>
<td>Transit Access</td>
<td>Very High</td>
<td>RN</td>
</tr>
<tr>
<td>Transit Access for Equity Emphasis Areas</td>
<td>None</td>
<td>RN</td>
</tr>
<tr>
<td>Transportation Demand Management</td>
<td>Low</td>
<td>CoGS</td>
</tr>
</tbody>
</table>

### ICAP Metric Priorities

<table>
<thead>
<tr>
<th>Metric</th>
<th>Priority</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Operations</td>
<td>High (3)</td>
<td>High Capacity Preservation VTrans priority; Several approaches operate at LOS E during</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>Moderate (2)</td>
<td>Pedestrian access not identified as a VTrans priority, but there is no pedestrian access to</td>
</tr>
<tr>
<td>Safety</td>
<td>High (3)</td>
<td>Multiple rear-end crashes between Centreport Pkwy and Iron Rd; Safety improvement</td>
</tr>
<tr>
<td>Cost</td>
<td>Low (1)</td>
<td>US Route 1 is classified as a corridor of statewide significance. A specific funding</td>
</tr>
</tbody>
</table>

### Volume Data, Crash History, and Multimodal Information

<table>
<thead>
<tr>
<th>Assessment Scenario Volume Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>---------------------------------</td>
</tr>
<tr>
<td>Eastbound</td>
</tr>
<tr>
<td>Westbound</td>
</tr>
<tr>
<td>Northbound</td>
</tr>
<tr>
<td>Southbound</td>
</tr>
</tbody>
</table>

### Existing Multimodal Accommodations

- **Pedestrian:** No existing pedestrian facilities or generators
- **Bicycle:** No existing bicycle facilities or generators
- **Transit:** I south of the Route 1/Route B intersection; Approximately 1,700’ from the Roy

### 5-Year Crash Data Summary (2016-2020)

<table>
<thead>
<tr>
<th>Crash Analysis Years</th>
<th>From 2015</th>
<th>To 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal + Injury Crashes</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Pedestrian Crashes</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Bicycle Crashes</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Figure 49: iCAP Assessment Output 1
### iCAP ASSESSMENT OUTPUT

#### Stage 1: Alternatives Screening Performance Matrix

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations Metric</th>
<th>Pedestrian Metric</th>
<th>Safety Metric</th>
<th>Stage 1 Cost Metric</th>
<th>Total Stage 1 Score</th>
<th>Selected for Stage 2 Analysis?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V/C Maximum V/C Ratio</td>
<td>Score</td>
<td>Score</td>
<td>Score</td>
<td>Score</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Accommodation</td>
<td>Conflict Points</td>
<td>Cost Category</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bus Lane</td>
<td>1.00</td>
<td>1.0</td>
<td>12</td>
<td>1.0</td>
<td>55</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous Green-T</td>
<td>0.07</td>
<td>0.8</td>
<td>0.0</td>
<td>0.0</td>
<td>12</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial Displaced L-</td>
<td>1.08</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>44</td>
<td>1.0</td>
</tr>
<tr>
<td>Turn Left SB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial Median U-</td>
<td>1.11</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>44</td>
<td>1.0</td>
</tr>
<tr>
<td>Turn Left SB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restricted Crossing</td>
<td>0.90</td>
<td>0.6</td>
<td>0.0</td>
<td>0.0</td>
<td>20</td>
<td>1.0</td>
</tr>
<tr>
<td>U-Turn Right SB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial Cloverleaf</td>
<td>0.00</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
<td>20</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Metric Weighting

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
</table>

#### Stage 2: Alternatives Assessment Performance Matrix

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations Metric</th>
<th>Pedestrian Metric</th>
<th>Safety Metric</th>
<th>Stage 2 Cost Metric</th>
<th>Total Stage 2 Score</th>
<th>Preferred Alternative?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MOE 1 Score</td>
<td>MOE 2 Score</td>
<td>Total Score</td>
<td>Score</td>
<td>Score</td>
<td>Score</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V/CX Crash Reduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V/CX Cost Estimate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous Green-T</td>
<td>0.1</td>
<td>0.1</td>
<td>0.0</td>
<td>0.30</td>
<td>1.0</td>
<td>2.5 out of 9</td>
</tr>
<tr>
<td>Restricted crossing</td>
<td>0.1</td>
<td>0.1</td>
<td>0.5</td>
<td>0.01</td>
<td>1.0</td>
<td>4.6 out of 9</td>
</tr>
<tr>
<td>U-Turn Left SB</td>
<td>1.0</td>
<td>1.0</td>
<td>0.5</td>
<td>0.08</td>
<td>1.0</td>
<td>4.1 out of 9</td>
</tr>
</tbody>
</table>

#### Metric Weighting

| 1 | 2 | 3 |

---

Figure 50: iCAP Assessment Output 2
Case Study #5: US Route 29 at Route A

This example project illustrates the application of the iCAP process at an interchange located along the APN that experiences congestion on the cross-street. The study location is an interchange between a business route and the bypass of that same route.

The intersection in this case study is a real location, however, for the purposes of Virginia iCAP policy and tool demonstration some data and location characteristics have been modified.

5.1 Project Introduction

5.1.1 Location Overview

This case study location is in Albemarle County, Virginia at the intersection of US Route 29 (29 Bypass Expressway) and Route A (Minor Street). US Route 29 is a four-lane, divided, freeway on the APN and Route A (Minor Street) is a two-lane, divided, principal arterial. This intersection, shown in Figure 51, provides access to the local street network east and west of the study interchange. The existing lane designations and traffic control are shown in Figure 52.

Figure 51: Aerial of Study Intersection
5.1.2 Purpose & Need

Identifying a project’s purpose and need helps the project team define project priorities and determine iCAP applicability. The project team identified the following concerns:

- **Traffic Operations**: Route A (Minor Street) currently experiences heavy volumes during both peak periods, but the PM peak-period sees the most congestion due to heavy left-turn movements from westbound Route A onto southbound US 29. This congestion leads to insufficient gaps for US 29 southbound off-ramp left-turn traffic to turn onto Route A. The afternoon queues along the US 29 southbound off-ramp extend into the mainline of US Route 29.

- **Safety**: There were 14 total crashes recorded within a 300-foot radius of the interchange from 2018 to 2022. 7 of the 14 total crashes were rear end collisions.

The historical crash data, along with the number of conflict points present at the existing intersection, and the presence of a nearby interchange led the project team to consider innovative intersection designs.

5.2 iCAP Applicability

The project team referenced the iCAP Tool “Applicability Flowchart” provided in Figure 1 to determine if an iCAP assessment is required.

**[A.1.1] Determine if the intersection is located on the APN**

US Route 29 is on the APN⁴²; therefore proceed to step A.2.1.

---

⁴² VDOT Arterial Preservation Network (APN) Map
https://vdot.maps.arcgis.com/apps/webappviewer/index.html?id=6a024b2739e44b5b8599d86aa3b2c6d7
Determine if the project purpose and need indicate traffic control should be evaluated

A change in traffic control at the intersection should be a consideration due to existing congestion at the interchange leading to safety concerns along US Route 29 southbound; therefore, proceed with step A.3.1.

Determine if issues at the location can be resolved with changes to signal timing and phasing

This step does not apply, as the study location is currently stop-controlled. Therefore, the intersection requires the full iCAP assessment and the project team should continue to the next step: A.4.

Complete Virginia iCAP Applicability Form

The form generated for this case study location is shown in Figure 53.

Once the VDOT District Traffic Engineer approved the iCAP Applicability Form, the project team scheduled a scoping meeting with VDOT and other project stakeholders.
Figure 53: Populated iCAP Applicability Form
5.3 Existing Needs

**A.5 Complete Virginia iCAP Tool General Input Worksheet**

To prepare for the scoping meeting, the project team populated the General Input Worksheet in the iCAP tool. Reference Section 3.2.2 of the iCAP Manual for guidance on completing this section.

The project team used the VTrans Mid-Term Needs and Priorities Map\(^{41}\) to identify any transportation needs at and in the vicinity of the study location as shown in Figure 54. This information was populated into the VTrans Needs and Priorities table included in the General Input Worksheet, shown in Table 40. In addition to the identified VTrans Needs and Priorities, the project team input the following information into the General Input Worksheet:

- **Existing and future V/C ratios\(^{42}\)**
  - Route A:
    - Existing: 0.47
    - Future: 0.52
  - US Route 29:
    - Existing: 0.71
    - Future: 0.90
- **PSI segment and intersection ranking\(^{43}\)**
  - 0.230 Mi of Route A, just east of this interchange ranked #133
  - 0.440 Mi of US Route 29 through this interchange ranked #49
  - No PSI Intersections
- **PSAP data\(^{44}\)**
  - Not a PSAP corridor
  - Not a bicycle and pedestrian generator

According to the VDOT Top Potential Safety Improvement Segments and Intersections Map there are two PSI segments within the study area, but no PSI intersections. Additionally, the study intersection is not located on a PSAP priority corridor or within a top crash cluster.

---

\(^{41}\) InteractVTrans Map Explorer. https://vtrans.org/interactvtrans/map-explorer

\(^{42}\) VA Statewide Planning Data Map.

\(^{43}\) Potential Safety Improvement (PSI) Map.
https://vdot.maps.arcgis.com/apps/webappviewer/index.html?id=36c14ce72fde488fb2ce3ed44377588d

\(^{44}\) Pedestrian Safety Action Plan (PSAP) Map.
Figure 54: 2019 VTrans Prioritized Mid-Term Needs
Prior to the scoping meeting, the project team developed draft metric weights to be used when ranking design alternatives. All of these metrics are important to maintaining a safe and efficient highway system, however, the nature of each project requires specific factors to be prioritized over others to best address the purpose and need of the project. The weighting system compares alternatives in a way that prioritizes the specific needs of a project, while still considering and valuing each metric. The project purpose and need, the historical crash data, the identified VTrans priorities, and preliminary engineering judgment were used to determine these draft metric weights. The metric weights developed for this project are shown in Table 41. For more information on metric weighting, reference Section 3.3 of the iCAP Manual.

**Table 41: Project Metric Weighting**

<table>
<thead>
<tr>
<th>Metric Weighting</th>
<th>Metric</th>
<th>Priority</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td></td>
<td>Priority</td>
<td>Justification</td>
</tr>
<tr>
<td>Traffic Operations</td>
<td>High (3)</td>
<td>The study was initiated due to existing congestion at the western interchange intersection that was resulting in queues that impacted southbound US Route 29 operations. Removing stopped vehicles from the freeway is the primary purpose and need of this project.</td>
<td></td>
</tr>
<tr>
<td>Pedestrian</td>
<td>High (3)</td>
<td>Accommodations end at the intersection and VTrans rates Bicycle Access as &quot;High&quot;</td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>Moderate (2)</td>
<td>14 crashes were recorded at the study location within the 5-year period. Safety improvement was flagged as a VTrans priority at the district level. Safety is an important aspect of this project, but the primary safety concern is related to queuing caused by congestion at the interchange. As a result, safety was weighted lower than traffic operations.</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>Low (1)</td>
<td>US Route 29 is classified as a corridor of statewide significance. A specific funding limitation was not identified.</td>
<td></td>
</tr>
</tbody>
</table>
The project team developed draft metric weights while completing the General Input Worksheet and presented each metric priority ranking along with proper justifications at the scoping meeting. VDOT and other project stakeholders approved the draft metric weights so the project team proceeded with these metric weightings in the iCAP analysis.

5.5 Scoping Meeting

Following the approval of the iCAP Applicability Form, the project team held a scoping meeting and discussed the project purpose and need, study limits, data requirements, Measures of Effectiveness (MOEs), and analysis tools required to perform the iCAP assessment, per Chapter 9 of the VDOT Traffic Operations and Safety Manual (TOSAM) and Section 2.2.1 of the iCAP Manual. The main outcomes from the scoping meeting are summarized below:

- **Study Area Limits:**
  - The project team and VDOT staff decided that the iCAP analysis would focus on the interchange intersections of US Route 29 and Route A (Minor Street). However, due to the proximity of the signalized intersection to the east of the interchange, along Route A, that intersection will be included in all capacity analyses to account for the impacts on each other.

- **Draft Metric Weighting:**
  - The DTE and other VDOT stakeholders felt that the metric weights aligned with the needs and priorities outlined in the General Input Worksheet, so they were approved for use with the iCAP tool.

- **Study MOEs:**
  - **Control delay** and the **95th percentile queue length** were selected as the MOEs for the analysis. The group collectively agreed that these were the most appropriate MOEs to evaluate performance at the study intersections, since addressing the queuing concerns caused by control delay is the primary purpose of this project.

---

• **Analysis Tools:**
  - The project team populated the VDOT Software Selection Tool (SST) Input Form with the location information and MOE selection and indicated that the interchange operates under undersaturated conditions.
  - The results from the VDOT SST indicated that HCS2022 was the most appropriate software to conduct the analysis.

• **Analysis Period:**
  - The project team and VDOT staff decided that the interchange alternatives would be evaluated for the 2045 horizon year in accordance with the available TDM horizon. Available 2022 turning movement counts were available at the study intersections to develop future no-build volumes prior to conducting the analysis.
  - The project scope and need highlighted congestion during the PM peak period as being of specific concern. As a result, the project team proposed conducting the iCAP analysis for the PM peak hour only to choose the interchange alternative that would best address the project’s purpose and need. However, the AM peak period will also be analyzed when designing the new interchange.

• **Data Collection:**
  - All existing conditions data was collected in year 2018. Historical crash data was obtained for the period between 2018 and 2022.

• **Analysis Alternatives:**
  - The DTE and other VDOT stakeholders expressed that they would prefer alternatives that did not require new bridges along US 29 to minimize operational impacts to US 29 as well as the significant costs associated with bridge reconstruction/widening.

### 5.6 Virginia iCAP Assessment Stage 1

The project team referenced the iCAP Tool “Stage 1 Flowchart” provided in Figure 2 to complete this phase of the assessment.

#### 5.6.1 Data Collection

*Input data into the Virginia iCAP Stage 1 Input Worksheet*

**Traffic Data**

Consistent with TOSAM and the Virginia iCAP process, the project team discussed the time periods, days, modes, and locations of count data needed during the scoping meeting. Available 2018 turning movement counts (TMCs) were available and it was agreed at the scoping meeting that those counts could be used in lieu of collecting new TMCs. The project team proposed the use of historical AADT data from VDOT count books to generate the volume growth rate used to grow the 2018 data to 2020 and generate 2045 volumes. The DTE and other VDOT stakeholders approved this methodology. The future (2045) AM (PM) peak hour turning movement counts are shown in Figure 55.

**Project-Specific Value:**

2045 traffic volumes were generated using an annual growth rate, which was determined using historical count data. The proposed growth rate was compared to the predicted growth in the region and approved by the DTE.
Multimodal Accommodations
There are currently no transit routes that travel through this interchange or are in close proximity to the east or the west. The existing bicycle and pedestrian accommodations (a shared-use trail along Route A) ends just to the east of this interchange. The study interchange is located near multiple bicycle and potential pedestrian generators - a medical research park, a shared-use trail, and a major university. The project team and VDOT stakeholders determined that a shared-use path should be included in a reconfiguration of the study interchange to connect the shared-use path and the shared-use trail located to the east of the interchange, to potential origin/destinations on the western side of the interchange.

The project team populated the Stage 1 Input Worksheet with the 2045 PM peak hour traffic volumes, the existing multimodal accommodations, and the historical crash data.

5.6.2 Stage 1 Operations & Safety Screening
The Stage 1 performance matrix screens interchange alternatives based on four metrics:

- Traffic operations
- Pedestrian
- Safety
- Stage 1 cost.

These metrics are reported from the Virginia Junction Screening Tool (VJuST).
1.2.1 Select alternatives in VJuST

When populating the VJuST Input Worksheet, the project team excluded several interchange designs due to right-of-way concerns and general infeasibility given the roadway facility types and traffic patterns. The excluded interchange types and the rationale for excluding them are presented in Table 42.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Considered?</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial Cloverleaf</td>
<td>No</td>
<td>Insufficient intersection spacing</td>
</tr>
<tr>
<td>Single Roundabout</td>
<td>No</td>
<td>Not feasible for the roadway facility type</td>
</tr>
</tbody>
</table>

The following alternatives were selected for consideration in VJuST: Traditional Diamond, Contraflow Left, Displaced Left Turn, Diverging Diamond, Double Roundabout, Michigan Urban Diamond, a Single Point interchange.

5.6.3 VJuST Assumptions

The project team documented the assumptions below, for conducting the VJuST analysis. These assumptions were based on available data and discussions with the DTE during the scoping meeting.

- The analysis was conducted using 2045 PM peak hour volumes.
- All adjustment factors and the truck passenger-car equivalent (PCE) factor were set to the default suggested values.
- Although it was assumed that the base number of through lanes remained the same as existing across all alternatives, the presence of turn lanes and lane sharing was altered for each alternative, primarily for both minor approaches.
- All interchange alternatives that were analyzed in VJuST, other than the Double Roundabout, were evaluated under the assumption that the primary intersection is signalized. This assumption cannot be changed, so it was taken into consideration when evaluating the results of the VJuST analysis.

Key Consideration:

In addition to the interchange alternatives highlighted in the table above, the project team did not consider any of the signalized or unsignalized intersection alternatives due to the nature of the interchange requiring geometries specific to interchanges.

5.6.4 Stage 1 Sketches

Create Stage 1 sketch for potentially viable alternatives

Stage 1 sketches were produced for each viable alternative evaluated in VJuST. The purpose of the Stage 1 sketch is to identify any high-level design constraints that could deem certain alternatives unviable. Reference Section 2.2.2 of the iCAP Manual for more information on the Stage 1 Conceptual Layout guidelines. Sketches were created for the following US Route 29/Route A interchange alternatives:

- Traditional Diamond
- Contraflow Left
- Displaced Left-Turn Interchange
- Diverging Diamond
- Double Roundabout
- Michigan Urban Diamond
- Single Point
For the purposes of this manual, a sample Stage 1 sketch is only provided for the selected alternative for the US Route 29/Route A interchange. A full iCAP analysis should include designs for each alternative selected for consideration. Figure 56 illustrates an example of a Stage 1 sketch for the displaced Left-Turn Interchange.

Figure 56: Displaced Left-Turn Interchange Stage 1 Sketch

5.6.5 Metric Performance Ranking

Evaluate and rank alternatives using the Virginia iCAP Tool Stage 1 Performance Matrix

Figure 57 shows the Stage 1 performance matrix, imported from VJuST. Reference Section 3.4.2 of the Manual for guidance on interpreting the values included in the Stage 1 Performance Matrix.
Figure 57: Stage 1 Performance Matrix
Of the seven total alternatives considered in Stage 1, three were selected for consideration in Stage 2: A signalized traditional diamond, a displaced left-turn interchange, and a double roundabout.

- **Signalized, Traditional Diamond:**
  - The signalized, traditional diamond advanced to Stage 2 since this alternative would not require modifications to the roadway geometry and resulted in a lower V/C ratio than the base condition.

- **Displaced Left-Turn Interchange:**
  - The Displaced Left-Turn Interchange advanced to Stage 2, despite its low Stage 1 score. The low score that this alternative received was based on the negative pedestrian ranking from VJuST, which does not account for designer’s ability to accommodate pedestrians through the interchange.
  - This alternative had the lowest V/C ratio, second only to a DDI from VJuST. A displaced left-turn interchange layout is one of the best alternatives to address the capacity concerns at this interchange which is the primary purpose and need of this study. Therefore, this alternative progressed to Stage 2, for further analysis/consideration.

- **Double Roundabout:**
  - The Double Roundabout layout had the highest Stage 1 score and would likely be feasible within the existing right-of-way constraints. Therefore, it progressed to Stage 2 for further consideration.

The remaining alternatives were not moved forward for the following reasons:

- **Contraflow Left:**
  - The Contraflow Left configuration is best suited to interchanges where both left-turn movements onto the ramps are heavy. At this interchange, only one of the left-turn movements is heavy, with the demand for the other left-turn movement remaining low throughout the forecasted future scenarios. A contraflow left would have been overkill at this interchange and was therefore removed from consideration and did not progress to Stage 2.

- **Diverging Diamond:**
  - A Diverging Diamond interchange would have served the needs of the project, but it would have also resulted in a much wider interchange footprint under the US 29 bridges resulting in the need for new bridges along US 29. The DTE and other VDOT stakeholders had previously expressed a preference for alternatives that would minimize bridge construction/modification requirements. To accommodate this preference, this alternative did not progress to Stage 2.

- **Michigan Urban Diamond**
  - A Michigan Urban Diamond interchange would require new bridges and ramps across US 29. The DTE and other VDOT stakeholders had previously expressed a preference for alternatives that would minimize bridge construction/modification requirements. To accommodate this preference, this alternative did not progress to Stage 2.

- **Single Point**
  - A Single Point interchange would require new bridges along US 29 to accommodate the width of the intersection under US 29. The DTE and other VDOT stakeholders had previously expressed a preference for alternatives that would minimize bridge construction/modification requirements. To accommodate this preference, this alternative did not progress to Stage 2.

The project team selected the Traditional Diamond, Displaced Left-Turn interchange, and the Double Roundabout for Stage 2 Analysis in the Stage 1 Performance Matrix and proceeded to the next step: 1.5 (Continue to Stage 2: Alternatives Assessment).
5.7 Virginia iCAP Assessment Stage 2

The project team referenced the iCAP Tool “Stage 2 Flowchart” provided in Figure 3 to complete this phase of the assessment.

5.7.1 Additional Data Collection

No additional data was required so the project team proceeded to the next step: 2.2 (Operations and Safety Performance Evaluation).

5.7.2 Operations & Safety Performance Evaluation

2.2.1 Perform operational analysis using appropriate tool per TOSAM

The Traditional Diamond, Displaced Left-Turn Interchange, and Double Roundabout alternatives were modeled and evaluated using HCS2023 and following the guidelines outlined in TOSAM. The project team generated HCM 6th edition reports for each alternative to use in the iCAP Stage 2 input worksheet. Prior to transferring the HCS2023 outputs into the input worksheet, the sheet was populated with the agreed-upon MOEs and the critical approach information.

2.2.2 Input results into the Virginia iCAP Tool Stage 2 Input Worksheet

The project team selected the 95th Percentile Queue Length and Control Delay MOEs and completed the critical approach inputs.

Key Consideration:

The project was initiated due to congestion along the southbound US 29 off-ramp in the PM peak-period caused by high-volumes along the westbound approach. As a result, the operational performance for the southbound and the westbound approaches were determined to be critical for evaluating alternatives. The eastbound and northbound approaches see heavy volumes during the AM peak-period, however, as discussed earlier in this report, these movements are adequately served by the existing interchange and were not part of the project’s purpose and need. They were therefore not considered as part of the critical approaches for consideration during the iCAP analysis.

QUEUING

The impact of queues on operations along Southbound US 29 was the primary motivating factor for this analysis. Analyzing the 95th percentile queues for the southbound approach to the interchange intersection is critical to addressing the primary purpose and need of this analysis to verify that the selected alternative will eliminate this safety concern. To determine whether queues are accommodated for each approach, the project team compared the HCM 95th Percentile Queues provided in the HCS2023 reports, like those shown in Figure 58, to the length of the storage provided for the respective movement.
Example Input for Displaced Left-Turn Interchange Alternative:

In the Displaced Left-Turn Interchange alternative, there is only one northbound approach. The results of the HCS2023 analysis, shown in Figure 58, found that the 95th Percentile Queue for the westbound approach (which was modeled as the SB approach in HCS2023 due to the complex geometries of a Displaced Left-Turn interchange intersection) is 992.8 feet long. This queue length can mostly be accommodated in the available storage space, but there will be some impacts to the previous intersection, which is 930’ east of this intersection. Table 43 illustrates how this information was transferred into the 95th Percentile Queue Length MOE Results table in the Stage 2 Input Worksheet.

Table 43: 95th Percentile Queue Length MOE Table for the Displaced Left-Turn Interchange Alternative

<table>
<thead>
<tr>
<th>95th Percentile Queue Length MOE Results</th>
<th>Input MOE</th>
<th># of Approaches</th>
<th>Westbound</th>
<th>Queues Acceptable?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 2</td>
<td>Displaced Left-Turn</td>
<td>95th Percentile Queue Length</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

In the No-Build (Base) alternative, the results of the HCS2023 analysis, shown in Figure 59, found that the 95th Percentile Queue for the southbound off-ramp approach is 64.5 vehicles long. This queue cannot be accommodated in the available ramp storage space, without spilling onto US 29 southbound.
Therefore, the project team indicated that none of the queues for the southbound approach could be accommodated in the 95th Percentile Queue Length MOE Table for this alternative (Table 44).

**Vehicle Volumes and Adjustments**

<table>
<thead>
<tr>
<th>Approach</th>
<th>Eastbound</th>
<th>Westbound</th>
<th>Northbound</th>
<th>Southbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Priority</td>
<td>1 U 1 T 3</td>
<td>4 U 4 T 6</td>
<td>7 U 8 T 9</td>
<td>10 U 11 T 12</td>
</tr>
<tr>
<td>Number of Lanes</td>
<td>0 0 1 0</td>
<td>0 0 1 0</td>
<td>0 0 0</td>
<td>0 1 0</td>
</tr>
<tr>
<td>Configuration</td>
<td>TR LT</td>
<td>LT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume (veh/h)</td>
<td>128 17</td>
<td>1225 46</td>
<td></td>
<td>390 0 64</td>
</tr>
<tr>
<td>Percent Heavy Vehicles (%)</td>
<td>5</td>
<td>5 5 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proportion Time Blocked</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent Grade (%)</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Right Turn Channelized</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median Type</td>
<td>Storage</td>
<td>Undivided</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Critical and Follow-up Headways**

<table>
<thead>
<tr>
<th></th>
<th>Eastbound</th>
<th>Westbound</th>
<th>Northbound</th>
<th>Southbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Critical Headway (sec)</td>
<td>4.1</td>
<td>7.1</td>
<td>6.5</td>
<td>6.2</td>
</tr>
<tr>
<td>Critical Headway (sec)</td>
<td>4.15</td>
<td>7.15</td>
<td>6.53</td>
<td>6.23</td>
</tr>
<tr>
<td>Base Follow-Up Headway (sec)</td>
<td>2.2</td>
<td>3.5</td>
<td>4.0</td>
<td>3.3</td>
</tr>
<tr>
<td>Follow-Up Headway (sec)</td>
<td>2.25</td>
<td>3.55</td>
<td>4.03</td>
<td>3.33</td>
</tr>
</tbody>
</table>

**Delay, Queue Length, and Level of Service**

<table>
<thead>
<tr>
<th></th>
<th>Eastbound</th>
<th>Westbound</th>
<th>Northbound</th>
<th>Southbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate, v (veh/h)</td>
<td>1332 498</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity, c (veh/h)</td>
<td>1404 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>v/c Ratio</td>
<td>0.95 1671.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>95th Queue Length, Qx (veh)</td>
<td>18.3 64.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Delay (s/veh)</td>
<td>310</td>
<td>776141.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level of Service (LOS)</td>
<td>D</td>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approach Delay (s/veh)</td>
<td>310</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approach LOS</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 59: Report Outputs from HCS2023 for the Base (No-Build) Condition - Two-Way Stop Control (TWSC)**

**Table 44: 95th Percentile Queue Length MOE Table for the Base (No-Build) Condition - TWSC**

<table>
<thead>
<tr>
<th>95th Percentile Queue Length MOE Results</th>
<th>Input MOE</th>
<th>Southbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td># of Approaches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Queues</td>
</tr>
<tr>
<td>Base Condition</td>
<td>No-Build</td>
<td>95th Percentile Queue Length</td>
</tr>
</tbody>
</table>
CONTROL DELAY
In addition to queuing information, the reports generated from HCS2023 included information on control delay. The project team populated the Stage 2 Input Worksheet with the control delays for all three alternatives and the base condition. Figure 60 illustrates the HCM Control Delay generated for the southbound off-ramp approaches for the Displaced Left-Turn Interchange alternative.

Key Consideration:
Some of the alternative interchange layouts maintained the southbound off-ramp from US 29 as an unsignalized, two-way stop controlled intersection. HCS2023 does not allow interchange intersections to be evaluated in the same model as un-signalized intersections. To analyze the operational impacts of the various alternatives to this key movement, separate TWSC analyses were performed for the various alternatives in HCS2023.

Both values were added together and transferred into the Control Delay MOE Results table (Table 45).

Figure 60: Report Outputs from HCS 2023 for the Displaced Left-Turn Interchange Alternative
Table 45: Control Delay MOE Results Table for the Displaced Left-Turn Interchange Alternative

<table>
<thead>
<tr>
<th>Control Delay MOE Results</th>
<th>Input MOE</th>
<th>Southbound Result</th>
<th>% Difference from Base Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 2</td>
<td>Displaced Left-Turn</td>
<td>71.1</td>
<td>99.98%</td>
</tr>
</tbody>
</table>

**EXPERIENCED TRAVEL TIME**

Following the selection of MOEs in the Stage 2 Input Worksheet, the iCAP tool automatically generated Experienced Travel Time (ETT) sheets for alternatives requiring ETT calculations, which for this analysis was only the Displaced Left-Turn Interchange alternative. The project team populated these sheets with the flow rate for each movement, the control delays for each lane group, the distances between each intersection, and the speed limit for each roadway. For example, the control delay reported from HCS2023, shown in Figure 61, is 17.1 seconds for the southbound approach. The project team manually populated this value into the corresponding “Delay” cell in the ETT sheet for the alternative (Table 46). This step was repeated for all relevant values. Once these sheets are populated with the required inputs, the iCAP tool automatically populates the calculated ETT values into the Stage 2 Input Worksheet.

**Table 46: Displaced Left-Turn Alternative EET Control Delay Inputs**

<table>
<thead>
<tr>
<th>Movement</th>
<th>Delay</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBL (1)</td>
<td>17.1</td>
<td>Northern Crossover (1)</td>
</tr>
<tr>
<td>SBT (1) – Free Movement</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>(Delay = 0 sec)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NBT (1)</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

**Key Consideration:**

The layout of the Displaced Left-Turn alternative does not have many of the movements in a typical Displaced Left-Turn intersection since this is an interchange and instead of an intersection. As such, the project team populated the iCAP ETT tables based on the reduced number of crossovers/accommodated movements present in this layout.
2.2.3 Review CMF for each potential alternative

The project team populated the Stage 2 safety weights using the SMART SCALE Round 5 Planning Level CMFs list\(^{46}\). The list does not contain appropriate CMFs for any of the interchange alternatives. Additionally, there are no CMFs listed in the Virginia State Preferred CMF List\(^{47}\), or the FHWA CMF Clearinghouse\(^{48}\) for these interchange alternatives. After consulting with the CO-TOD safety planning team, the project team took a conservative approach and left the CMF as the default value of 1.0, which projected no reduction in the number of crashes.

5.7.3 Stage 2 Sketch & Cost

2.3.1 Create Stage 2 sketch for each alternative

Following the completion of the operations and safety evaluation, the project team produced Stage 2 sketches for each evaluated alternative. These sketches not only depict each allowable turning movement, but also include proposed and existing pavement areas, existing property lines, and right-of-way impacts. An example of a Stage 2 sketch is shown in Figure 62. Reference Section 2.3.2 of the Manual for more information on the Stage 2 Sketch guidelines.

---

46 SMART SCALE Round 5 Planning Level CMFs. https://smartscale.org/documents/2022/round_5_cmf_list.pdf

Figure 62: Displaced Left-Turn Interchange Stage 2 Sketch
**2.3.2 Complete Stage 2 construction cost estimate for each alternative**

The project team input the VJuST-C Planning Level Cost Estimate for each alternative to represent the Stage 2 cost metric. These estimates, which include the total engineering and construction costs, were generated using the VJuST-C tool.

**Key Consideration:**

The project team assumed that none of the alternatives will impact right-of-way or need modifications to the bridges along US 29. However, these factors are not able to be modified in VJuST-C. Therefore, it was assumed that the total engineering and construction costs would be lower than estimated. The comparative numbers can be used for purposes of Alternative Selection.

The total costs generated for the study interchange alternatives were manually input into the Stage 2 Performance Matrix, as shown in Table 47.

<table>
<thead>
<tr>
<th>Intersection Type</th>
<th>Consider?</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Diamond (Signalized)</td>
<td>Yes</td>
<td>$33,568,000</td>
</tr>
<tr>
<td>Displaced Left-Turn Interchange</td>
<td>Yes</td>
<td>$33,658,000</td>
</tr>
<tr>
<td>Double Roundabout</td>
<td>Yes</td>
<td>$29,489,000</td>
</tr>
</tbody>
</table>

**5.7.4 Metric Performance Ranking**

**Evaluate and rank alternatives in the iCAP Tool Stage 2 Performance Matrix**

Figure 63 shows the completed Stage 2 Performance Matrix for the study interchange. Reference Section 3.5.2 of the Manual for guidance on interpreting the values included in the Stage 2 Performance Matrix.
### Figure 63: Stage 2 Performance Matrix

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations</th>
<th>Pedestrian</th>
<th>Safety</th>
<th>Stage 1 Cost</th>
<th>Total Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Diamond</td>
<td>0.5</td>
<td>0.5</td>
<td>1.00</td>
<td>$33,568,000</td>
<td>3.4</td>
</tr>
<tr>
<td>Displaced Left-Turn</td>
<td>1.0</td>
<td>1.0</td>
<td>1.00</td>
<td>$33,658,000</td>
<td>3.75</td>
</tr>
<tr>
<td>Double Roundabout</td>
<td>0.9</td>
<td>1.0</td>
<td>1.00</td>
<td>$29,489,000</td>
<td>5.55</td>
</tr>
</tbody>
</table>

**Preferred Alternative and Justification**

**Traditional Diamond**
- No: The queues for this alternative are unacceptable. The operational needs of the project will not be met with this alternative.

**Displaced Left-Turn**
- Yes: This alternative will best serve the operational needs of this project. The pedestrian accommodations laid out in the Stage 2 sketch were unable to be accounted for in the tool, so the pedestrian weighting is artificially lower which is why this alternative did not rank higher.

**Double Roundabout**
- No: The queues are acceptable for this alternative, however, some movements had V/C ratios above 1. Therefore this alternative is less desirable.
• **Traditional Diamond (Signalized)**
  - The Traditional Diamond alternative resulted in queue lengths that would impact the operations of up-stream intersections. The movement delay and queues were still significantly better than the no-build operations, but there were still movements with V/C ratios above one and queues that exceeded their storage length.

• **Displaced Left-Turn Interchange**
  - The Displaced Left-Turn Interchange resulted in the lowest control delay, with acceptable queues and V/C ratios below one for all movements.
  - The construction costs for all three alternatives were similar in magnitude, but this alternative had slightly higher costs than the other two alternatives.
  - The tool does not account for multimodal availability of this alternative that was added in the Stage 2 layout stage, which gave this alternative an artificially lower ranking in the iCAP results.

• **Double Roundabout**
  - The Double Roundabout alternative had movements with V/C ratios above one. While this alternative did not have queue lengths that would impact operations at other intersections, the Displaced Left-Turn Interchange alternative better served the operational needs of the interchange.

Due to the acceptable operational performance and the highest iCAP Stage 2 rating, the project team selected the Displaced Left-Turn Interchange as the preferred alternative.

### 5.8 Documentation & Submittal

Following the completion of the iCAP assessment, the project team exported the iCAP Assessment Outputs, shown in Figure 64 and Figure 65, from the tool. These documents, along with the following items, were submitted to the VDOT DTE or the assigned designee for approval:

- Memo, which documents assessment assumptions and preferred alternative
- Virginia iCAP Tool
- Virginia iCAP Applicability Form
- VJuST output
- Stage 1 and Stage 2 sketches
- VJuST-C output
- Synchro outputs
- Traffic analysis and safety data

IIM-TOD-397 contains more information on the reporting and approval requirements for Virginia iCAP assessments.
Figure 64: iCAP Assessment Output 1
### iCAP ASSESSMENT OUTPUT

#### Stage 1: Alternatives Screening Performance Matrix

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Traffic Operations Metric</th>
<th>Pedestrian Metric</th>
<th>Safety Metric</th>
<th>Stage 1 Cost Metric</th>
<th>Stage 1 Score</th>
<th>Selected for Stage 2 Analysis?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Condition</td>
<td>1.34</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Traditional Diamond</td>
<td>0.74</td>
<td>0</td>
<td>0.5</td>
<td>28</td>
<td>0.0</td>
<td>$1.0</td>
</tr>
<tr>
<td>Contraflow Left</td>
<td>0.74</td>
<td>0</td>
<td>0.5</td>
<td>32</td>
<td>0.0</td>
<td>$$0.5</td>
</tr>
<tr>
<td>Displaced Left Turn</td>
<td>0.56</td>
<td>-</td>
<td>0.0</td>
<td>28</td>
<td>0.0</td>
<td>$0.5</td>
</tr>
<tr>
<td>Diverging Diamond</td>
<td>0.54</td>
<td>1.0</td>
<td>0</td>
<td>20</td>
<td>0.7</td>
<td>$$$0.3</td>
</tr>
<tr>
<td>Double Roundabout</td>
<td>0.99</td>
<td>0.4</td>
<td>+ 1.0</td>
<td>16</td>
<td>3.0</td>
<td>$0.5</td>
</tr>
<tr>
<td>Michigan Urban Diamond</td>
<td>0.71</td>
<td>0.4</td>
<td>+ 1.0</td>
<td>24</td>
<td>0.3</td>
<td>$$$0.2</td>
</tr>
<tr>
<td>Single Point</td>
<td>0.70</td>
<td>0.0</td>
<td>-</td>
<td>32</td>
<td>0.0</td>
<td>$$$0.2</td>
</tr>
</tbody>
</table>

#### Stage 2: Alternatives Assessment Performance Matrix

<table>
<thead>
<tr>
<th>Alternative</th>
<th>MOE 1 Score</th>
<th>MOE 2 Score</th>
<th>Total Score</th>
<th>Preferred Alternative?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Diamond</td>
<td>1.0</td>
<td>1.0</td>
<td>0.5</td>
<td>No: The queues for this alternative are unacceptable. The operational needs of the project will not be met with this.</td>
</tr>
<tr>
<td>Displaced Left Turn</td>
<td>0.9</td>
<td>0.9</td>
<td>0.0</td>
<td>Yes: This alternative will best serve the operational needs of this project.</td>
</tr>
<tr>
<td>Double Roundabout</td>
<td>0.7</td>
<td>0.7</td>
<td>1.0</td>
<td>No: The queues are acceptable for this alternative, however, some movements had V/C ratios above 1. Therefore, this</td>
</tr>
</tbody>
</table>

#### Metric Weighting

<table>
<thead>
<tr>
<th>Traffic Operations Metric</th>
<th>Pedestrian Metric</th>
<th>Safety Metric</th>
<th>Stage 1 Cost Metric</th>
<th>Total Stage 1 Score</th>
<th>Stage 2 Score</th>
<th>Preferred Alternative?</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOE 1 Score</td>
<td>MOE 2 Score</td>
<td>Total Score</td>
<td>Annual Fat/Cost Reduction</td>
<td>Score</td>
<td>ViST-C Cost Estimate</td>
<td>Score</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Figure 65: iCAP Assessment Output 2**
APPENDIX B

Virginia iCAP Reviewers Prompt List
### VIRGINIA iCAP REVIEWERS PROMPT LIST

**PROJECT INFORMATION**

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPC Number</td>
<td>State Project Number</td>
</tr>
<tr>
<td>Project Location</td>
<td>VDOT District</td>
</tr>
<tr>
<td>City/County</td>
<td></td>
</tr>
</tbody>
</table>

Are any project intersections or interchanges on the VDOT Arterial Preservation Network?

<table>
<thead>
<tr>
<th>VDOT Project Manager</th>
<th>Locality/Agency Project Manager</th>
<th>Agency Partner Project Manager</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Project Type/Analysis Category</th>
</tr>
</thead>
</table>

### VIRGINIA iCAP ASSESSMENT REVIEW

#### iCAP APPLICABILITY

- Completed and signed iCAP Applicability Form
- Completed General Input Worksheet, including justification for metric weighting
- Conducted scoping meeting to determine study limits, MOEs, analysis tools, etc.

#### STAGE 1: ALTERNATIVES SCREENING

- Completed Stage 1 input worksheet
- VJuST output
- Justification for why each alternative was or was not advanced to Stage 2
- Stage 1 sketches for viable alternatives

#### STAGE 2: ALTERNATIVES ASSESSMENT

- Traffic analysis tool output(s) from analysis tool(s) selected per the VDOT TOSAM
- Additional traffic analysis and safety data
- Documentation of CMFs used
- Stage 2 refined sketches for each alternative
- VJuST-C output
- Justification for why each alternative was or was not selected as the preferred alternative

#### DOCUMENTATION AND REPORTING

- Virginia iCAP Tool output
- Memo, which documents assessment assumptions and preferred alternative
- Warrant study if a traffic signal is part of the recommended alternative per IIM-TE-387

#### COMMENTS

---

1. [https://www.virginiadot.org/programs/vdot_arterial_preservation_program.asp](https://www.virginiadot.org/programs/vdot_arterial_preservation_program.asp)
APPENDIX C

Virginia iCAP Tool Metric Scoring Methodology
## Virginia iCAP Tool Metric Scoring Methodology

### Example Stage 1 Performance Matrix

<table>
<thead>
<tr>
<th>Metric Weighting (Based on Purpose and Need)</th>
<th>Traffic Operations</th>
<th>Pedestrian</th>
<th>Safety</th>
<th>Stage 1 Cost</th>
<th>Total Possible Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternatives</td>
<td>VJuST Maximum V/C Ratio</td>
<td>Traffic Operations Metric MOE Score</td>
<td>VJuST Accommodation Compared to Conventional</td>
<td>VJuST Pedestrian MOE Score</td>
<td>VJuST Weighted Total Conflict Points</td>
</tr>
<tr>
<td>Existing Conventional</td>
<td>1.00</td>
<td>--</td>
<td>0</td>
<td>--</td>
<td>48</td>
</tr>
<tr>
<td>Alternative 1 Bowtie NB-SB</td>
<td>0.90</td>
<td>0.7</td>
<td>+</td>
<td>1.0</td>
<td>24</td>
</tr>
<tr>
<td>Alternative 2 Conventional</td>
<td>0.93</td>
<td>0.5</td>
<td>0</td>
<td>0.5</td>
<td>48</td>
</tr>
<tr>
<td>Alternative 3 Quadrant Roadway S-W</td>
<td>0.86</td>
<td>1.0</td>
<td>0</td>
<td>0.5</td>
<td>40</td>
</tr>
<tr>
<td>Alternative 4 Restricted Crossing U-Turn EB-WB</td>
<td>0.92</td>
<td>0.6</td>
<td>0</td>
<td>0.5</td>
<td>20</td>
</tr>
</tbody>
</table>

#### Metric

**Traffic Operations**
- VJuST Maximum V/C Ratio

**Pedestrian**
- VJuST Pedestrian Accommodation Compared to Conventional

**Safety**
- VJuST Weighted Total Conflict Points

**Stage 1 Cost**
- VJuST Planning Level Cost Category

**General equation:**

\[
\text{Score} = \frac{\text{MOE Score} \times \text{Weighting}}{\text{Total Possible Score}}
\]

#### Measure of Effectiveness (MOE)

**VJuST Maximum V/C Ratio**

- **Score**
  - Based on the reduction in maximum V/C ratio for each alternative from the base condition (Existing).
  - Normalized to the highest reduction in V/C ratio of the alternatives assessed.
  - If no reduction in V/C from base condition, score = 0.0
  - Possible score range = 0.0-1.0

**VJuST Accommodation Compared to Conventional**

- **Score**
  - Based on whether the alternative qualitatively accommodates pedestrians better (1.0), similar (0.5), or worse (0.0) when compared to a conventional intersection or traditional diamond interchange.
  - If no reduction in conflict points from base condition, score = 0.0
  - Possible score range = 0.0-1.0

**VJuST Weighted Total Conflict Points**

- **Score**
  - Based on the reduction in total weighted conflict points for each alternative from the base condition (Existing).
  - Normalized to the maximum reduction in conflict points of the alternatives assessed.
  - If no reduction in conflict points from base condition, score = 0.0
  - Possible score range = 0.0-1.0

**VJuST Planning Level Cost Category**

- **Score**
  - Based on the Stage 1 cost category value, normalized to the lowest cost category of the alternatives assessed.
  - If no reduction in conflict points from base condition, score = 0.0
  - Possible score range = $ (1) / $$$ (3)

#### Example Calculation for Alternative 1 (Bowtie)

- **Highest reduction in V/C ratio** = 1.00 – 0.86 = 0.14
- **Alternative reduction in V/C ratio** = 1.00 – 0.90 = 0.10
- **Score** = 0.10 / 0.14 = 0.7

- **Highest reduction in conflict points** = 48 – 20 = 28
- **Alternative reduction in conflict points** = 48 – 24 = 24
- **Score** = 24 / 28 = 0.9

- **Lowest cost category** = $ (1)
- **Alternative cost category** = $$$ (3)
- **Score** = $ (1) / $$$ (3) = 0.3

**Total Score:**

\[
1.4 + 2.0 + 2.7 + 0.3 = 6.4
\]
### Example Stage 2 Performance Matrix

<table>
<thead>
<tr>
<th>Metric Weighting (Based on Purpose and Need)</th>
<th>Traffic Operations</th>
<th>Pedestrian</th>
<th>Safety</th>
<th>Stage 2 Cost</th>
<th>Stage 2 Total Possible Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alternatives</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bowtie NB-SB</td>
<td>42.8</td>
<td>1.0</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restricted Crossing U-Turn EB-WB</td>
<td>79.9</td>
<td>0.5</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Measure of Effectiveness (MOE)

- **Traffic Operations**
  - Control Delay*
  - Microsimulation Delay*
  - V/C Ratio
  - (A score is not calculated for the 95th Percentile Queue Length nor Maximum Queue Length MOEs)

- **Pedestrian**
  - VJuST Pedestrian Accommodation Compared to Conventional

- **Safety**
  - Projected annual reduction in fatal and injury crashes calculated using a Crash Modification Factor (CMF)

- **Stage 2 Cost**
  - VJuST-C Total Estimated Engineering and Construction Cost

#### Score

- **Traffic Operations**
  - Output from traffic and safety analysis tool consistent with TOSAM and scoping meeting decision

- **Pedestrian**
  - VJuST

- **Safety**
  - SMART SCALE Planning Level CMF, Virginia Preferred CMF List, or FHWA CMF Clearinghouse

- **Stage 2 Cost**
  - VJuST-C

#### General equation:

\[ \text{General equation:} \quad \text{MOE Score x Weighting} \]

\[ \begin{align*}
\text{Traffic Operations} & : 0.5 \times 2 = 1.0 \\
\text{Pedestrian} & : 0.5 \times 2 = 1.0 \\
\text{Safety} & : 0.7 \times 3 = 2.1 \\
\text{Stage 2 Cost} & : 1.0 \times 1 = 1.0 \\
\text{Total Score} & : 1.0 + 1.0 + 2.1 + 1.0 = 5.1
\end{align*} \]

#### Example Calculation for Restricted Crossing U-Turn Alternative

- **Lowest control delay result** = 42.8
- **Alternative control delay result** = 79.9
- **Score** = 42.8 / 79.9 = 0.5

#### Converts Total MOE score to the average metric MOE score of the two MOEs selected. For this example, a score is not calculated for the 95th percentile queue MOE, so the total MOE score for Alt. 2 is 0.5.

- **Qualitatively similar accommodation than a conventional intersection, 0.5**

#### Highest expected reduction in crashes = 2.1
- **Alternative expected reduction in crashes = 1.5**
- **Score** = 1.5 / 2.1 = 0.7

#### Lowest VJuST-C cost estimate = $4.285M
- **Alternative VJuST-C cost estimate = $4.285M**
- **Score** = $4.285M / $4.285M = 1.0

*Reported as experienced travel time (ETT) for certain innovative intersection and interchange configurations.