Primer on Intersection Control Evaluation (ICE)

What is ICE?

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. A growing number of transportation agencies are developing and adopting ICE policies. Although there are differences among these ICE policies, they are consistent in emphasizing *transparency*, *flexibility,* and *adaptability*.

Agencies with ICE policies are realizing several benefits, including:

- Implementation of safer, more balanced, and more cost-effective solutions.
- Consistent documentation that improves the transparency of transportation decisions.
- Increased awareness of innovative intersection solutions and emphasis on objective performance metrics for consistent comparisons.
- The opportunity to consolidate and streamline existing intersection-related policies and procedures, including access or encroachment approvals, new traffic signal requests, and impact studies for development.

When is ICE used?

ICE policies are generally applicable to intersections along State highways or any intersection project that will utilize Federal or State funds. ICE is recommended, but not required, for intersection projects off the State system and involving funding other than Federal or State.

ICE is required for new intersections or when considering any substantive changes to the traffic control or geometry of existing intersections. Definitions for what constitutes substantive changes to intersections vary by agency. Substantive changes are often considered for the following reasons:

- Safety improvement.
- Congestion mitigation.
- Broader corridor improvement/widening.
- Multimodal facility enhancement.
- Change of access to an adjacent parcel of land or land development.

ICE policies are intended to be flexible and adaptable. There are situations where ICE is not needed because the work does not include any substantive proposed changes to an intersection. Some States with ICE policies provide example triggers for and exemptions to conducting ICE.

ICE procedures are also intended to occur as part of an established project development process. ICE has a significant influence on the development of intersection-specific projects, as the selection of intersection and control type are central decisions of those projects. On corridor improvement projects, results from ICE may serve as the basis of not only the major intersection type and control decisions but the nature of access management along the entire corridor. Regardless of the project type, ICE conducted at the appropriate time of project development contributes to more confident project programming decisions, more thoroughly vetted geometric and control solutions, and a smoother progression of the project.

What does ICE look like?

ICE procedures are flexible and scalable and encourage a level of analysis consistent with the questions that need to be answered and decisions that need to be made on a specific project. A streamlined analysis may be appropriate for some projects, with sketch-level evaluations being sufficient. Projects with high levels of complexity may require a more robust effort. The fundamental principles of ICE, however, are the same, regardless of the level of detail and whether it is being applied for new intersections or modifications to existing intersections.

ICE is typically conducted in two stages:

- A "Stage I – Scoping" step to determine the short list of all possible alternatives that merit further consideration and analysis because they meet project needs and are practical to pursue.
- A "Stage II – Alternative Selection" step to determine the preferred alternative based on more detailed evaluations conducted during typical preliminary engineering activities.

For some projects where Stage I results in only one viable alternative, the alternative selection documentation is based on the Stage I analysis and results.

Stage I – Scoping

The purpose of the scoping phase of ICE is to determine, from dozens of potential alternatives, which few intersection type and control solutions merit further consideration for the project. The scoping phase of ICE occurs early in project development, helping to inform a project scope and develop a cost estimate and schedule. It is important to note that the purpose of Stage I is not to compare intersection alternatives against each other but to assess the alternatives individually to determine if and to what extent they potentially meet project purpose and need, strategic program goals, project context, and funding constraints.

Intersection Alternatives

It is common for ICE policies to identify and describe the intersection type and control solutions to be considered during Stage I. This information generally includes basic descriptions and illustrations of the alternatives, known benefits or concerns, and links to additional resources (including those described in the "Resources" section of this primer).

Stage I Scoping Analysis

The Stage I scoping analysis involves a combination of quantitative and qualitative performance metrics. The Stage I analysis should be sufficient enough to estimate a preliminary footprint of each intersection alternative to determine whether it is practical to pursue and to answer the following questions:

- Does the alternative meet the transportation purpose and need?
- Does the alternative address the key system performance criteria (e.g., safety, non-motorized user accommodation, operational quality, etc.)?
- Does the alternative meet the needs and values of the local community and directly-affected stakeholders?

Safety Analysis. The Stage I safety analysis should provide a basis to characterize safety performance of the possible alternatives. This distinction may rely on both qualitative and quantitative methods. The safety analysis in the scoping phase generally determines one of the following, depending on the project intent:

- If improving safety is the primary need for a project, does the intersection alternative address the safety need by enhancing safety performance?
- If improving safety is not the primary need for a project, does the intersection alternative maintain or enhance safety performance?

Operational Analysis. The Stage I operational analysis also considers both qualitative and quantitative methods. The primary goal of the operational analysis in the scoping phase is to determine if the intersection alternative will perform at an acceptable quality of service. Appropriate traffic control device warrant analyses may be conducted during Stage I. ICE generally focuses on the specific intersection (isolated) or intersections (corridor) under consideration for improvement, but evaluations may sometimes need to extend beyond to assess impacts on adjacent intersections or facilities.

Multimodal Considerations. The suitability of each alternative for pedestrians and bicyclists should be assessed with an emphasis on convenience and accessibility and consideration of pedestrian and bicyclist network information from local and community plans. Potential items to consider include number of lanes to cross, protected versus permitted turning movements, and motorist approach speeds. Additionally, the multimodal assessment should consider the suitability of each alternative for transit, freight, and other large vehicle operations when applicable. The Stage I scoping analysis with respect to freight and other large vehicle operation can be informed by whether an intersection is part of a designated Truck Route or Over-Size-Over-Weight Route. Transit assessments can be informed by discussions with the transit provider about different treatment options and any operating restrictions associated with different intersection and control types.

Other Considerations. Even if an alternative addresses needs from an operational and safety perspective, a number of other considerations may determine whether it is a practical option to pursue. These include the following:

- Right-of-way, environmental impacts, and construction costs.
- Constructability timelines, staging, temporary traffic control needs, and project delivery.
- Acceptability of the alternative by the public, local jurisdictions, and other important stakeholders.
- Consistency within interregional corridors or other highways where a corridor study has been prepared.

Stage II – Alternative Selection

Stage II is intended to differentiate among the intersection alternatives brought forward from the Stage I screening analysis. Stage II analysis is conducted as part of preliminary engineering and includes the estimating of environmental, utility, and right-of-way impacts. The analysis occurs at a level of detail that allows objective comparisons of alternatives to each other. Stage II evaluates each viable alternative based on the following aspects:

- Safety performance (motorized and non-motorized).
- Operational performance (present vs. projected, peak vs. off-peak).
- Cost.
- Benefit-cost.
- Environmental, utility, and right-of-way impacts.
- Multimodal accommodations (pedestrian, bike, transit).
- Public opinion and input.
- Other factors specific to the context (e.g., consistency with future land use, transportation plans for the surrounding area).

The Stage II safety and operational analyses assess and document performance measures using tools and methodologies such as those in the *Highway Safety Manual*, *Highway Capacity Manual*, simulation software, and other applicable methodologies. These measures can be monetized to support a benefit-cost analysis, allowing an agency to consider the "value added" by an improvement in relation to cost.

Resources and Tools to Support ICE

Several useful resources and tools for conducting ICE are available or currently in development. These resources and tools are organized into the following categories: 1) intersection reference guides, 2) operational and safety performance evaluation tools, and 3) life-cycle cost analysis tools. Transportation agencies that have implemented ICE policies have also developed corresponding resources, some of which are forms and worksheets that make up the required ICE documentation.

Intersection Reference Guides

Informational guides that discuss applications, designs, and performance characteristics of different intersection types and control strategies are available to support Stage I (Scoping) and Stage II (Alternative Selection) activities of ICE, including the following:

- **Unsignalized Intersections Improvement Guide (UIIG)**.
  The UIIG aids practitioners in selecting design, operational, maintenance, enforcement, and other types of treatments to improve the safety, mobility, and accessibility of all users at unsignalized intersections. It is a web-based resource hosted at http://toolkits.ite.org/uiig/.

- **Signalized Intersections: An Informational Guide, 2nd Edition** (FHWA-SA-13-027).
  This document serves as an introduction to and guide for evaluating the safety, design, and operations of signalized intersections, and emphasizes achieving solutions for all users. It can be downloaded at https://go.usa.gov/xP9p8.

- **Roundabouts: An Informational Guide, 2nd Edition** (NCHRP Report 672).
  This document provides introductory material about roundabouts and addresses the planning, design, construction, maintenance, and operation of roundabouts in the United States. It can be downloaded at http://www.trb.org/Publications/Blurbs/164470.aspx.

- **Displaced Left-Turn Intersection Informational Guide** (FHWA-SA-14-068).
  This document provides information and guidance on the planning, design, construction, maintenance, and operation of Displaced Left Turn (DLT) intersections. It can be downloaded at https://go.usa.gov/xP9Ar.

- **Median U-Turn Intersection Informational Guide** (FHWA-SA-14-069).
  This document provides information and guidance on the planning, design, construction, maintenance, and operation of Median U-Turn (MUT) intersections. It can be downloaded at https://go.usa.gov/xP9Ab.

- **Restricted Crossing U-Turn Intersection Informational Guide** (FHWA-SA-14-070).
  This document provides information and guidance on the planning, design, construction, maintenance, and operation of Restricted Crossing U-Turn (RCUT) intersections. It can be downloaded at https://go.usa.gov/xP9AZ.

- **Diverging Diamond Interchange Informational Guide** (FHWA-SA-14-067).
  This guide provides information and guidance on the planning, design, construction, maintenance, and operation of diverging diamond interchanges. It can be downloaded at https://go.usa.gov/xP9AB.

- **Alternative Intersections and Interchanges Informational Report** (FHWA-RD-09-060). This report provides information on over a dozen alternative intersection and interchange designs that may offer additional benefits compared to conventional at-grade intersections and grade-separated interchanges. It can be downloaded at https://go.usa.gov/xP9AX.

Safety and Operational Performance Evaluation Tools

The following tools help ICE practitioners quantify the expected performance characteristics of different intersection types and control strategies for a given context and are available to support Stage I (Scoping) and Stage II (Alternative Selection) activities of ICE:

- **Highway Safety Manual (HSM)**. The HSM provides methodologies to conduct safety performance analyses, allowing for safety to be quantitatively evaluated alongside other transportation performance measures such as traffic operations, environmental impacts, and construction costs. With the HSM, the expected change in crash frequency and severity of different design alternatives can be compared to the operational benefits or environmental impacts of these same alternatives. Tools available to conduct HSM analyses can be found at http://www.highwaysafetymanual.org/Pages/Tools.aspx.

- **Safety Performance for Intersection Control Evaluation (SPICE)**. This Excel spreadsheet-based tool performs an HSM-based predictive safety analysis of at-grade intersection alternatives/control types and ramp terminal intersections. The SPICE tool is intended for planning-level safety analysis, such as during ICE Stage I. The SPICE Tool can be downloaded at https://safety.fhwa.dot.gov/intersection/ice/.

- **Highway Capacity Manual (HCM).** The HCM contains concepts, guidelines, and computational procedures for estimating the capacity, operational performance, and quality of service of various highway and street facilities, including freeways, multilane highways, urban streets, roundabouts, signalized and unsignalized intersections, and rural, two-lane highways. The HCM includes a *Planning and Preliminary Engineering Applications Guide (PPEAG)*, published as the National Cooperative Highway Research Program (NCHRP) Report 825, that provides best practices for using the HCM in a variety of planning and preliminary engineering applications. The Highway Capacity Software (HCS) implements HCM procedures. The HCM and HCS may be purchased from the Transportation Research Board (TRB) bookstore.

- **Capacity Analysis for Planning of Junctions (CAP-X)**. This Excel spreadsheet-based tool can be used to evaluate various intersection types using peak flow volumes and lane configurations as inputs. The output is a volume-to-capacity ratio for each intersection type based either on critical lane volume summations or HCM equations. The CAP-X tool provides a sketch-planning level operational analysis for use during ICE Stage I. The latest version of CAP-X can be downloaded at https://safety.fhwa.dot.gov/intersection/ice/.

- **Traffic simulation models.** Simulation software exists to aid traffic engineers in traffic analysis, optimization, and simulation of new intersection projects. The software supports the HCM methodologies for signalized intersections, unsignalized intersections, and roundabouts. Some agencies provide default simulation templates for various alternative intersection types as part of their ICE resources (i.e., Jughandle, MUT, Quadrant Roadway, RCUT, DLT, Diverging Diamond, and Continuous Green T-Intersection).

Life – Cycle Cost Analysis Tools

ICE incorporates a number of considerations in screening and assessing intersection alternatives, including safety performance, operational and capacity considerations, and right-of-way, utility, and environmental impacts and costs. NCHRP project 3-110, *Estimating the Life-Cycle Cost of Intersection Designs*, produced a spreadsheet-based tool that

supports the comparison of life-cycle costs of alternative designs for new and existing intersections. The tool considers crashes, vehicular delay, emissions, operations and maintenance, and capital costs. The report (NCHRP Web-Only Document 220) and the tool may be downloaded at http://www.trb.org/Publications/Blurbs/173928.aspx.

Agency – Developed Tools and Templates

Transportation agencies have developed their own tools or modified existing tools to aid in a consistent and repeatable implementation of ICE. Agencies have also developed documentation templates to aid in consistent documentation of decisions made during ICE, including the following:

- **ICE Worksheets.** These worksheets are either in a document or spreadsheet format and guide an ICE process by providing placeholders for key user-specified inputs. The worksheets can serve as ICE documentation, which creates consistency for all projects requiring ICE. The user-specified inputs generally include crash data, traffic volumes, practical feasibility, costs, and geometric features of the intersection.
- **Traffic Control Summary Tables**. These tables generally include illustrations or pictures of intersection types and control solutions, when to consider the alternatives, potential benefits, safety considerations, operational considerations, and links to additional information. Depending on the State, this information can be found as a chapter or appendix in an agency's guidance/manual document or as a tab in an ICE Worksheet.
- **Tables of Intersection Safety Treatments**. These tables show potential intersection safety treatments based on the types of conflicts the agency desires to address.
- **ICE Submittal Checklists.** These documents identify required and optional submittals associated with each stage of ICE. The required documentation includes project description, traffic volume data, safety considerations, operational analysis, highway capacity worksheets, and various traffic modeling outputs.
- **Technical Support and Training.** It is important to establish a program to provide ICE technical assistance and training for both internal and external stakeholders. This provides avenues for consultation on complex or controversial access proposals, strategies, or concepts, as well as the assessment, scoping, analysis, and design of innovative access strategies. Over time, an agency's capacity to support ICE will grow and a fully institutionalized practice may be realized.
- **Completed Examples.** Some agencies provide completed examples of memoranda and worksheets to aid evaluators during the process. It is also common for agencies to provide examples of completed ICE reports to serve as reference for future projects.

Appendix: State Transportation Agency Resources

California
Caltrans ICE webpage: http://www.dot.ca.gov/trafficops/ice.html
Caltrans ICE Policy Directive: http://www.dot.ca.gov/trafficops/policy/13-02.pdf
Caltrans ICE Process Informational Guide: http://www.dot.ca.gov/trafficops/docs/ICE_ProcessInformationalGuide.pdf

Florida
FDOT Intersection Operations and Safety webpage:
http://www.fdot.gov/traffic/TrafficServices/Intersection_Operations.shtm
FDOT Manual on ICE:
http://www.fdot.gov/traffic/TrafficServices/Studies/MICE/FDOT%20ICE%20Manual_FINAL_11011766.pdf
FDOT ICE Form: http://www.fdot.gov/traffic/TrafficServices/Studies/MICE/FDOT%20ICE%20Forms_20180411.xlsx

Georgia
GDOT Manuals & Guides: http://www.dot.ga.gov/PS/DesignManuals/DesignGuides
GDOT ICE Tool v2.14 spreadsheet:
http://www.dot.ga.gov/PartnerSmart/DesignManuals/Intersection%20Control%20Evaluation/GDOT%20ICE%20Tool.zip

Indiana
Intersection Decision Guide: https://www.in.gov/indot/files/ROP_IntersectionDecisionGuide.pdf

Minnesota
MnDOT's ICE webpage: http://www.dot.state.mn.us/trafficeng/safety/ice/
MnDOT ICE Manual: http://www.dot.state.mn.us/trafficeng/safety/ice/2007_ICE_Manual.pdf

Nevada
NDOT's ICE Policy: https://www.nevadadot.com/home/showdocument?id=14229 (see Appendix D)

Pennsylvania
PennDOT's ICE Documentation Tool:
http://www.dot.state.pa.us/public/Bureaus/BOMO/Portal/PennDOT%2520ICE%2520Forms_January%25202018.xlsx
PennDOT's ICE Evaluation Tool: http://www.dot.state.pa.us/public/Bureaus/BOMO/Portal/PennDOT_ICE_Tool_V1.1.xlsm

Washington State
Washington State Design Manual - Intersection Control Type:
http://www.wsdot.wa.gov/publications/manuals/fulltext/M22-01/1300.pdf

Wisconsin
WisDOT's Traffic Analysis, Modeling, and Data Management webpage, including WisDOT's Facilities Development Manual (ICE is on pg. 41 — FDM 11-25-3): http://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/programs/analysis/default.aspx

FHWA-SA-18-076

U.S. Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
Investment in roadway safety saves lives
http://safety.fhwa.dot.gov