ICE Process Informational Guide

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ICE Process Steps & Outcomes

Process Steps

#1. SCREENING
Engineering Assessment of Intersection Control Options & other Strategies

1 Typically performed during the Traffic Investigation, Local Development Review and PSR / PDS processes

Outcomes / Products

Elimination of options & strategies that fail to meet the established need, or that are impractical to implement

Performance Analysis Findings:
- Safety: estimated cost / savings
- Mobility: est. delay cost / savings

Life-Cycle / Economic Analysis Findings:
- Service Life (estimated years)
- Benefit / Cost Index
- Future Investment Needed

Note 3: See Appendix B for guidance
ICE Process Step One
Assessment “screening” to Identify Practical / Viable Intersection Control Strategies

Consultation with “Sponsor” to understand context and need for new access or access modification
Identify intersections & strategies to be evaluated

Collect Traffic & Collision Data / Aerial Mapping

Conduct Traffic Engineering Assessment
- Planning-level Capacity Analysis to “size” infrastructure needed; that is: “foot print”
- Assess relative safety performance
- Warrant analysis (can be deferred to Step 2)

Draw “foot print” & Assess to identify general impacts

Identify Options / Strategies for further study
Document Findings & Recommendation

To Step 2

Note 1: Consult with District ICE Coordinator and/or ICE TAP specialists
ICE Process Step Two: Project-level Engineering, Economic & Comparative Analyses

1. Prepare preliminary plans
   - Evaluate layout plans\(^1\) and revise to optimize;
   - prepare cost estimates
2. Traffic Engineering Studies\(^1\)
   - estimate of performance impacts & benefits
   - Service Life analysis
3. Economic Analyses: B/C Index & Life-Cycle
4. Document findings & recommend preferred control or access management strategy

Signed by District engineer\(^2\)

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Notes:
1. Consult with District ICE Coordinator and designated specialists
2. The engineering functional manager responsible for intersection control strategies, typically the District Highway Operations Engineer or District Traffic Safety Engineer

More than one alternative recommended?  

from Step 1

Yes  No
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PART B: ACCESS STRATEGIES & CONFIGURATIONS

NOTE: See FHWA website for information on many of the access strategies listed below:

Intersection Traffic Control Systems / Strategies
1) Yield (Roundabouts)
2) Stop \(\rightarrow\) minor leg or multi-way
3) Signalization
   i. Full or “half”
   ii. Pedestrian Crossings (Warning Systems & Hybrid Beacon)

At-Grade Intersection Configurations
1) Conventional
   i. Crossing-type: typically 4-legs at right angles
   ii. Circular: Roundabouts (Mini, Single Lane and Multi Lane)
2) Reduced Conflict Access Concepts
   i. Restricted Crossing with U-Turn
   ii. Median U-Turn
   iii. ThrU Turn (for narrow medians)
   iv. Diverging Diamond (double crossover) Interchange
3) Alternative Concepts
   i. Displaced Left Turn
   ii. Continuous Green Tee
   iii. Offset Tee Pair
   iv. Jughandle (aka New Jersey Left)
   v. Quadrant Roadway
   vi. Bowtie
   vii. Split
   viii. Paired

Pedestrian Crossing Control Strategies
1) Rectangular Rapid Flash Beacon
2) Pedestrian Hybrid Beacon (aka HAWK)
3) Raised Crosswalk
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Partial Grade-Separated Intersection Designs

1) Center Turn Overpass
2) Echelon
3) Windmill

Local Service Interchanges (with two or more ramp terminal intersections)

1) See Chapter 500 of the Highway Design Manual for Configurations
2) Double Roundabout (aka Teardrop or Raindrop)
3) Single Point Roundabout
4) Diverging Diamond (aka Double Crossover)
5) Compressed Diamond
6) Offset Left (aka Contraflow)
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PART C: Evaluation Process Steps, Activities & Outcomes

Section C-1.0: General Guidance

The guidance presented herein is informational and subject to change as experience and research & development efforts produce more accurate information, planning-level and analytical tools for the various evaluation activities that identify practical alternatives and recommendations on effective intersection control & access management strategies and configurations.

The ICE process is triggered by transportation and local development planning, the traffic investigation and project initiation processes. ICE process steps and activities are an integral part of these business processes. In particular, the screening process is part of the broader Traffic Engineering Performance Assessment (TEPA) performed during the project initiation process that produces a Project Study Report (Project Development Support Only). See PDPM Chapter 9, Article V for additional guidance on the TEPA.

The design of every intersection type, configuration or concept involves an engineering decision to implement an intersection traffic control system or strategy. Local service interchanges are typically comprised of two or more independent intersections (i.e. ramp termini). Nearly every state highway intersection features one of the following control strategies:

- Two-way stop control (or minor leg stop control for “tee” intersections); this is the “default” strategy which assumes that the major or primary traffic movement is the state highway through movement
- All or multi-way stop control (regardless of number of approaches)
- Signalization
- Yield-control (the roundabout)

Intersection control decisions are guided and supported by the intersection control evaluation process. ICE findings and recommendations rely upon the identification and evaluation of other critical infrastructure components; specifically those needed to:

- provide access and capacity for all users
- ensure a reasonable level of safety and operational performance for all users
- accommodate all uses and users, especially commercial vehicle operators, emergency responders, and those who work to operate and maintain the intersection
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Intersection and interchange infrastructure components include:

- basic geometric design features; for example: the number of through lanes, channelization lanes, shoulders, bike lanes, sidewalks, curb ramps, horizontal curve or curb return radii to facilitate or restrict traffic movements
- traffic control devices; for examples: signs, beacons and markings
- appurtenant features / systems; for example: curbed islands, drainage systems, lighting, landscaping, etc.

The complete scope of intersection infrastructure is determined after engineering and environmental studies are performed to identify the various design and operational elements, features and systems required for the safe and efficient operation and maintenance of each intersection and interchange.

Section 2.0 Pre-ICE Activities: Setting the Foundation for Step One

The ICE process (see process diagram in Part A) cannot begin until:

- the affected intersection or interchange owner/operators have a clear understanding of the need and/or the value expected from an access-related investment proposal
- a reasonable number of access strategies or configurations are identified for consideration

Once the need is understood, it is then possible to identify and agree upon access solution concepts that can be expected to meet the need in an effective, practical and context-appropriate manner. In order to ensure that all proven and emerging solution concepts are considered, the engineer who is performing an intersection control evaluation (i.e. ICE engineer) should consult with the District ICE Coordinator and/or refer to the most current list of access strategies, configurations and concepts. See the ICE TOPD website for a link to the most current list. Also, see the “Screening Tool” in Section C-3.3.1.

The ICE engineer is encouraged to consider innovative strategies and concepts when the need and context warrant a special solution. There is not a minimum or target for the number of access solution concepts to be evaluated via the ICE process. However, there will be situations where several solution concepts may be considered to be worthy of ICE assessment activities.

The “screening” step is most valuable when several access concepts are identified as potential solutions for a given need and access investment proposal.
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Section C-3.0: ICE Step One: Assessment / Screening of Access Concepts

The guidance presented in section C-3 should be applied with engineering judgment to identify access concepts that merit further consideration as project alternatives during the Project Approval & Environmental Approval (PA & ED) phase of the project development process.

Section C-3.1 – Screening Objectives

The primary objective of the screening process is to identify access solution concepts that can be dropped from further consideration to avoid the unnecessary expenditure of planning and engineering resources during the PA & ED phase of the project development process when formal design, traffic and environmental studies are performed for each alternative.

Assessment and screening activities are performed to identify access solution concepts that are both viable and practical to implement as defined below:

- **viable** access concepts are those which can be demonstrated or expected to meet the established need in a manner that is timely, context appropriate, and sensitive to community values
- **practical** access concepts are those which can be implemented without incurring substantial resource impacts (i.e. environmental, cultural, historical and/or financial).

When the ICE Step One Assessment effort determines that a potential solution concept is not viable or practical to implement, the concept can be dropped from further consideration unless there is a difference opinion among the ICE engineer, the project sponsor, and the local agency / community representative. In such cases, it may be appropriate to advance the solution concept in question to the next phase of the project development process (during which detailed engineering studies will be performed).

C-3.2 Capacity Assessment / Analysis

In order to determine if an access strategy or configuration is both viable and practical to implement, the engineer must first determine the size or footprint of the access concept. This is usually accomplished through a planning-level capacity calculation (analysis) to identify the number and approximate length of lanes needed along each approach leg in order for a specific intersection control strategy to operate with an acceptable safety and operational level-of-performance.
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The capacity analysis methodology should be selected and employed by a qualified practitioner. Practitioner judgment should be exercised in the selection of an analytical tool that is appropriate for the quality and completeness of traffic volume data that is readily available or provided. For example, during the development of a PSR-PDS, it is possible that existing and future peak hour turning volumes will not be available. If this is the case, then it may be necessary to make general assumptions about peak volumes (e.g. based on ADT) and the size or footprint of each access solution concept. This will make it difficult to “screen out” control strategies and configuration, except in cases where the estimated design year peak period traffic is obviously beyond the range of volumes for which multi-way stop control is effective.

When existing and design year peak period turning movement volumes are not available, the screening process will be completed during the subsequent phase of the project development process. In other words, screening will be completed as part of the formal traffic analysis. In such cases, the project sponsor will need to program / allocate resources to perform detailed traffic engineering studies of multiple intersection control and/or interchange alternatives during the PA & ED phase. However, one or more access solution concepts may be dropped from further consideration as soon as the ICE engineer determines that a concept is not viable or practical to implement.

C-3.3 Screening Criteria for Intersections (includes Ramp Terminii)

The critical or controlling criteria for intersections include design standards and various traffic engineering, design and project development principles and objectives. The criteria vary depending on the specific type, control strategy and/or configuration. For example, the capacity, safety and operational performance of a roundabout relies primarily upon the speed environment produced by a combination of geometric design and other highway features (e.g. curbed islands). Whereas, the controlling criteria for crossing type intersections are different (e.g. the use of curbs may be undesirable).

Therefore, this section will emphasize the importance of understanding that:

- specific criteria apply to all intersections
- the criteria apply uniquely to different intersection types and configurations
- certain intersection control strategies & configurations have unique criteria

NOTE: The screening process will not always produce definitive findings or results because there is usually a limit to the level of analysis and/or resources expended during transportation and project planning activities.
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The following criteria apply to all or most access solution concepts:

1. The number and arrangement of through and channelization lanes should provide adequate capacity (for design year peak traffic) and effective lane utilization.

2. Intersection control warrants should be met for design year operating conditions
   a. or access concepts that rely upon signal and multi-way stop control
   b. see “Screening Tool” guidance and table in Section C-3.3.1

3. Sight distance and visibility should be provided for driver recognition of the intersection, its control devices, and conflicting user

4. The through and legal turning movements of design vehicles (e.g., commercial, agricultural and emergency vehicles) should be accommodated; note: design vehicles may not be permitted to operate on all legs of the intersection, so it may not be necessary to accommodate turning movements to/from these legs

5. Specific design features and traffic control devices/systems should be provided to meet the needs of pedestrians and bicyclists; specifically:
   a. To accommodate through, crossing & turning movements
   b. To manage speed differential at conflict points, or separate the conflicting movements with the appropriate traffic control system

6. Local community input (through consultation with a local agency representative) is needed to ensure that the design is context appropriate and sensitive to their needs and values.

In addition to the above criteria:

- See Section 3.4 for general information and references to design guidance, standards, practices and performance objectives
- Refer to Section 3.4.1 for criteria and guidance that is unique to roundabouts.
- For access strategies and configurations that are unconventional or unique to the area, the ICE engineer or designer are advised to consult with an ICE specialist and seek a formal peer review by practitioners who have relevant and specialized knowledge and/or experience with the access concept.

Section C-3.3.1 Initial Screening Tool

The traffic volume ranges and thresholds presented below in Table 1 can be used to facilitate the screening process. The Average Daily Traffic ranges represent the total volume of vehicles entering an intersection. The values are approximate, so if the total ADT is near a threshold, consideration should be given to performing an assessment of both strategies.
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<table>
<thead>
<tr>
<th>Total ADT Entering</th>
<th>All-Way Stop</th>
<th>Signal</th>
<th>Yield (RBT)</th>
<th>Grade Separation</th>
</tr>
</thead>
<tbody>
<tr>
<td>7,500 - 15,000</td>
<td>X</td>
<td></td>
<td>X (single-lane)</td>
<td></td>
</tr>
<tr>
<td>15,000 - 25,000</td>
<td>X</td>
<td>X</td>
<td>X (single-lane)</td>
<td></td>
</tr>
<tr>
<td>25,000 - 80,000</td>
<td>X</td>
<td>X</td>
<td>X (multi-lane)</td>
<td></td>
</tr>
<tr>
<td>&gt;80,000</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Table 1 – Suggested Intersection Control Strategies by Total ADT Entering

C-3.4 Footprint Development & Assessment

Assuming that traffic data is sufficient to identify the number of approach lanes needed for the peak period of the design year peak, the ICE engineer or designer can develop a footprint for each intersection control strategy and configuration. The footprint should be developed in accordance with:

- the criteria presented in Section 3.3
- the design guidance provided or referenced in the Highway Design Manual, especially guidance on the application of established engineering standards, practices and design performance objectives.

NOTE: The development of the footprint for innovative access strategies, including the roundabout and Diverging Diamond Interchange, will be more challenging if the ICE engineer or designer does not have prior experience. However, practitioners are advised to seek and use the following resources to develop and evaluate any and all innovative, unconventional and non-conforming access proposals:

- the newly established ICE Technical Assistance Program

A sketch of the footprint on scaled aerial mapping or as-built plan will allow for an assessment of each strategy from the following perspectives:

- constructability (which informs cost estimating)
- impacts to businesses, homes, parks and land (including geological features) that are highly valued by the community
- impacts to environmental resources
- Investment needed (order of magnitude cost)

The ICE engineer or designer should consider making adjustments to the initial footprint
when the context of the highway facility and location warrant customization and flexibility in the application of engineering standards and practices. It is important to recognize that operating speeds are a critical feature of a highway facility's context. In particular, existing and future approach speeds are among the most important factors to consider when attempting to determine if the intersection footprint can be adjusted to "fit" the context. In low speed environments, it can be easier to make design adjustments in order to avoid significant impacts to the community, environment or amount of the investment without incurring significant (or any) impact to the capacity, safety or operational performance of the intersection.

3.4.1 Roundabouts: The adequacy of proposed roundabout geometry can be evaluated and demonstrated using design performance checks focused on the attainment of the design objectives and principles presented in section 6.2 (and throughout Chapter 6) of NCHRP Report 672, "Roundabouts, An Informational Guide," 2nd Edition. In particular, it is imperative that roundabout geometry (i.e. the inscribed circle diameter and the width of the circulatory roadway and truck apron) be able to accommodate all legal turning movements of the appropriate design vehicle without adversely impacting intersection capacity, operation and safety for all other users. Design vehicles can turn through different radii, but the swept width increases as the radius decreases. Therefore, various geometric design combinations can accommodate design vehicle turning and off-tracking. Truck turning software is needed to determine if a specific combination of geometric features will accommodate design vehicle movements through the roundabout.

It should be noted that the same requirement applies to the design of conventional crossing type intersections where turning trucks move more slowly than other motor vehicles, and sometimes use all lanes (and shoulders) of the receiving roadbed.

Approach speeds and speed management are among the most important factors and determinants of the scope and design of roundabout intersections. Optimal performance will be produced when the design produces visibility (sight distance and visual cues), vehicle paths and a speed environment that optimizes the capacity and safety along the approach and departure legs, and through the circulatory roadway:

- Where high-speed vehicles decelerate prior to the upstream pedestrian crossing and entrance to the circulating roadway
- Prior to downstream pedestrian crossings.

Like all or most intersection types, high speed approaches warrant the consideration of additional features and the use of design criteria that are not appropriate for low speed operating conditions. It is important to emphasize that the unwarranted use of roundabout design criteria for high-speed environments or large design vehicles will
often have a detrimental effect on the safety and operational performance of a roundabout in a low to moderate speed environment, especially since this will increase vehicle speeds & speed differential among the various users at crossing & conflict areas.

Roundabouts can be “screened” from further consideration where:

- they would be located within a highway corridor with an inter-connected and synchronized signal system that would be disrupted by the roundabout
- the footprint would have a major impact on the built environment compared to signalization for the same design year (NOTE: signalization may require greater right of way acquisition when additional through and channelization are needed to provide the capacity needed in the design year)

C-3.5 Safety Considerations

All access strategies and configurations will provide a nominal level of safety when the scope of features is complete, and the design substantially conforms with established standards, criteria and guidance. However, the assessment of intersection solution concepts may benefit from consideration of the relative safety performance characteristics of control strategies. For example, relevant safety research studies and Highway Safety Manual Collision Modification Factors for the basic control strategies in specific situations or environments can be cited to “screen” signalization from further consideration, but only when there is little or no risk to the timely implementation of the roundabout.

However, it is important to include “multi-way stop control” and signalization in the project development process as interim countermeasures in cases where the ICE process has been triggered by a traffic safety investigation. It may be reasonable to consider the interim installation of multi-way stop control or a traffic signal based on collision history and the expected timeframe for environmental and public approval of the roundabout alternative. Unless there is prior local experience and therefore support for the roundabout, it is usually prudent to include signalization as an alternative (in case the roundabout alternative is too controversial to implement in a timely manner).

C-3.6 Examples. See Part D of this Guide for basic examples of how access strategies and configurations are initially identified (a pre-ICE activity), and how they can dropped via Step One (assessment and screening) activities.
C-3.7 Role of Consultation

The ICE engineer is expected to rely upon or consult with District functional units and the District ICE Coordinator, who may recommend consultation with appropriately qualified members of the ICE Technical Assistance Program (TAP) prior to completion of the screening step. The ICE TAP is available to provide technical assistance and advice when there is uncertainty or disagreement regarding the viability or practicality of access solution concepts, especially innovative strategies for which there is little or no District operational experience. Contact the District ICE Coordinator for additional information.

C-3.8 Recommendations and Documentation

The outcome of the Assessment / Screening effort (ICE Step One) is a written recommendation prepared and signed (or concurred in writing) by the District Traffic Operations engineer responsible for the subject intersection or corridor.

The initial investment cost (alone) is usually not a reason to “screen” an access strategy or configuration, especially when the solution concept is expected to produce significant performance benefits in terms of the estimated reduction in collisions, severe collisions, delay, queuing, trip travel time, and life-cycle costs (from maintenance and operation of the intersection and its control strategy). In other words, an alternative with a higher initial capital cost may produce a “Return on Investment” (ROI) that is significantly higher than the ROI for the lowest cost alternative.

The documentation shall identify:

- the access strategies, configurations or concepts that should be advanced for further consideration as alternatives for each specific intersection and interchanges within the limits of the planning study, traffic investigation or project initiation effort that triggered the ICE process.
- the other access strategies and configurations considered, and a brief discussion as to the reason these solution concepts were dropped from further consideration (cite applicable screening criteria from Section C-3.3)
- the name of individuals (with their affiliation) consulted during the screening process, especially the local agency representative, the District ICE Coordinator and specialists whose input was used to “drop” specific access concepts
Section 4.0 -- Step Two: Project-level Analysis (under revision)
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PART D: Examples / Samples

Section 1.0: ICE Step One (Case Studies will be “imported” from training material)

Section 2.0: ICE Step Two (Case Studies will be “imported” from training material)

Section 3.0: SAMPLE Memo of Findings & Recommendation from ICE Screening; see Attachment A

Section 4.0: Template for Documentation / Summary of ICE Technical Findings

<table>
<thead>
<tr>
<th>Control Option or other Strategy</th>
<th>Estimated Cost To implement ($)</th>
<th>Estimated Service Life (no. of years)</th>
<th>Estimated DELAY (peak periods)</th>
<th>Estimated COLLISION Cost or Savings ($)</th>
<th>Benefit vs. Cost Index (optional)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop Only on Minor Legs (baseline)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multi-Way Stop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield (RBT)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Alt Strategy #1 (optional)</td>
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</tr>
<tr>
<td>Alt Strategy #2 (optional)</td>
<td></td>
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</tr>
</tbody>
</table>

SAMPLE Template for Summary of ICE Technical Findings
PART E: Additional Background Information & Resources

(still "under construction")
Kittelton & Associates, Inc. (KAI) conducted an Intersection Control Evaluation (ICE) to objectively evaluate and screen intersection control and access alternatives at the following intersections:

1. El Toro Street/El Rio Road
2. US 505 Eastbound Ramp Terminal/El Rio Road
3. US 505 Westbound Ramp Terminal/El Rio Road
4. Gato Road/El Rio Road

The control options traffic signal control and roundabouts. The City of Langdon owns and operates intersections 1 and 4. Intersection 4 was considered as the fifth leg of a roundabout at the US 505 Westbound Ramp Terminal/El Rio Road intersection and for relocation approximately 210 feet to the north to maximize spacing between the intersections. Operationally, each of these configurations could serve forecast traffic and each concept is viable. There may be other considerations and project factors identified in future design evaluations helping to prioritize a specific configuration.

The intersection evaluations considered year 2035 traffic operations (including service life and life cycle cost considerations) and geometrics and other design considerations.

Key findings include:

- Roundabout forms appear to be the practical alternative based upon funding available for this city-funded project. Signal concepts require widening the highway overpass and results in costs beyond programmed funding.
- The roundabout alternatives at intersections 1, 2 and 3 retain the existing US 505 overpass bridge. Traffic signal alternatives would require reconstructing the bridge.
- The roundabout intersection alternatives were found to perform better than traffic signal alternatives in almost all criteria.
- The safety comparison predicts a reduction in total and serious and minor injury crashes by converting the traffic signal controlled intersections to roundabouts.
- Traffic signal operations would not be acceptable in the 2035 design year and would require additional exclusive turn lanes at all three intersections.
- In addition to the cost savings realized by retaining the existing bridge, the geometric design considerations favor the roundabout alternatives.

The roundabouts will provide speed control and the required sight distance, as well as accommodate all traffic movements for the STAAA and emergency response design vehicles. The roundabout alternative allows for less complex guide signing through the intersections; whereas the traffic signal requires specific lane designations. Additionally, the roundabout alternatives have better expected safety performance than the traffic signal alternatives.

KAI recommends the roundabout alternatives be advanced as viable intersection control and access strategies for the El Toro Street/El Rio Road, US 505 Eastbound Ramp Terminal/El Rio Road, and US 505 Westbound Ramp Terminal/El Rio Road intersections. KAI also recommends advancing a Gato Road concept including Gato Road as the fifth leg of the US 505 Westbound Ramp Terminal/El Rio Road roundabout and a concept creating a separate Gato Road intersection.

Tables 1 and 2 summarize analysis findings. Caltrans and the City of Langdon have met, reviewed findings and recommendations and agree with advancing roundabouts as viable intersection control and access strategies. Figure 1 shows a concept design.
### Table 1. Year 2035 Operations Comparison

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Year 2035 Existing Signal Control</th>
<th>Year 2035 Mitigated Signal Control</th>
<th>Year 2035 Roundabout Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>El Toro Street/El Río Road</td>
<td>• Over capacity</td>
<td>• Under capacity</td>
<td>• Under capacity</td>
</tr>
<tr>
<td></td>
<td>• Average delay of 88 seconds in the weekday p.m. peak hour</td>
<td>• Average delay of 34 seconds in the Saturday midday peak hour</td>
<td>• Average delay of 15 seconds in the Saturday midday peak hour</td>
</tr>
<tr>
<td></td>
<td>• Inadequate queue storage</td>
<td>• Adequate queue storage</td>
<td>• Adequate queue storage</td>
</tr>
<tr>
<td>US 505 Eastbound Ramp Terminal/El Río Road</td>
<td>• Under capacity</td>
<td>• Under capacity</td>
<td>• Under capacity</td>
</tr>
<tr>
<td></td>
<td>• Average delay of 21 seconds in the weekday p.m. peak hour</td>
<td>• Average delay of 16 seconds in the Saturday midday peak hour</td>
<td>• Average delay of 10 seconds in the Saturday midday peak hour</td>
</tr>
<tr>
<td></td>
<td>• Inadequate queue storage</td>
<td>• Adequate queue storage</td>
<td>• Adequate queue storage</td>
</tr>
<tr>
<td>US 505 Westbound Ramp Terminal/El Río Road</td>
<td>• Under capacity</td>
<td>• Under capacity</td>
<td>• Under capacity</td>
</tr>
<tr>
<td></td>
<td>• Average delay of 43 seconds in the weekday p.m. peak hour</td>
<td>• Average delay of 26 seconds in the weekday p.m. peak hour</td>
<td>• Average delay of 15 seconds in the Saturday midday peak hour</td>
</tr>
<tr>
<td></td>
<td>• Inadequate queue storage</td>
<td>• Adequate queue storage</td>
<td>• Adequate queue storage</td>
</tr>
</tbody>
</table>

**Bold** indicates unacceptable operations

1. Also includes Gato Road approach under roundabout control
2. Overall intersection operations shown for the signalized alternatives
3. Mitigation includes widening the El Río Road bridge over US 505

### Table 2. Performance Comparison – Life Cycle Costs

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Signal</th>
<th>Roundabout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations &amp; Maintenance – Lowest Cost</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Landscaping Maintenance – Lowest Cost</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Pavement Rehabilitation – Lowest Cost</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>US 505 Bridge – Lowest Cost</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Crash Costs – Lowest Cost</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

### Figure 1. Concept Design