INTERSECTION SAFETY AND OPERATIONAL ASSESSMENT PROCESS GUIDE

Division of Traffic Operations
California Department of Transportation

SEPT 2024

Contents

Introduction

The *Intersection Safety and Operational Assessment Process (ISOAP) Guide* presents a data-driven, performance-based framework incorporating the Safe System Approach to screen intersection strategies and identify optimal solutions for new or improved intersections. ISOAP objectively helps select intersection control and geometric designs for the expected users within the context of an intersection's location. Land use and place type are to be considered in determining appropriate intersection strategies. The process recognizes that support resources can be limited to develop and implement feasible strategies and is an evolution of, and successor to, the Intersection Control Evaluation (ICE) policy and procedures. This guide accompanies the memorandum establishing ISOAP and supersedes the *ICE Process Informational Guide 1.0*.

Background

In 2013, Traffic Operations Policy Directive (TOPD) 13-02 established ICE as a requirement for determining traffic control at intersections to optimize all viable forms of traffic control. The ICE policy led to additional guidance, streamlined documentation and approval, provided a formalized support network, and supported successful project implementation.

The following resources support and necessitate the update of TOPD 13-02:

- Intersections are one of the 16 identified Challenge Areas in the *2020-2024 Strategic Highway Safety Plan (SHSP)*. In California over the 10-year period from 2011-2020, crashes related to intersections represented 24% of all fatalities and serious injuries, and roughly one third of these were pedestrians and bicyclists. The *2020-2024 SHSP* incorporated the following Guiding Principles that are pertinent to the ISOAP: Integrate Equity, Double Down on What Works, Accelerate Advanced Technology, and Implement the Safe System Approach.
- Director's Policy 36 (DP-36) on Road User Safety adopts the Safe System Approach as the basis for a vision of zero road fatalities and serious injuries by 2050. As stated in DP-36, the Safe System Approach aims to eliminate fatal and serious injuries for all road users through a holistic view of the road system. It further states that the policy establishes a corporate expectation to prioritize safety, and for all Divisions to align their programs, plans, policies, procedures, and practices with the Safe System Approach. In summary, there is a "Safety First" mindset prioritizing road safety.
- Director's Policy 37 (DP-37) on Complete Streets "establishes Caltrans' organizational priority to encourage and maximize walking, biking, transit, and passenger rail as a strategy to not only meet state climate, health, equity, and environmental goals but also to foster socially and economically vibrant, thriving, and resilient communities. To achieve this vision, Caltrans will maximize the use of design flexibility to provide context-sensitive solutions and networks for travelers of all ages and abilities."

The emergence of Safe System-oriented assessment tools, such as the Safe System-Based Framework and Methodology for Assessing Intersections, developed by the Federal Highway Administration (FHWA), provide an analytical basis for assessing project-level alternatives according to Safe System principles and elements.

Safe System Approach

The Safe System Approach is based on six principles:

- Eliminate death and serious injury.
- Humans make mistakes.
- Humans are vulnerable.
- Responsibility is shared.
- Redundancy is crucial.
- Safety is proactive and reactive.

The five elements of the Safe System Approach are the following:

- Safe road users
- Safe vehicles
- Safe speeds
- Safe roads
- Post-crash care

Intersection safety performance (crash frequency and severity) can be enhanced by incorporating the principles of the Safe System Approach and addressing several of the elements. Safety is considered for all road users, including those who walk, bike, drive, or ride transit. Reducing speed at locations of potential conflict lessens the likelihood of a crash and severity of crashes. Safe roads are designed to be forgiving should a driver make a mistake.

Strategies for Safe System intersections can include the following:

Minimizing and modifying conflict points.

A traditional four-legged intersection with single lane approaches has 32 vehicular conflict points, including 16 crossing, 8 merging, and 8 diverging conflicts points as shown in Figure 1. The crossing conflicts could potentially result in the most severe crash types. In comparison, a four-legged single-lane roundabout has 8 vehicular conflict points, including 4 merging and 4 diverging conflict points, as shown in Figure 2. Therefore, any crash that occurs in a roundabout would typically be less severe than in a traditional intersection

Figure 1. Traditional Four-Legged Intersection with Single Lane Approaches

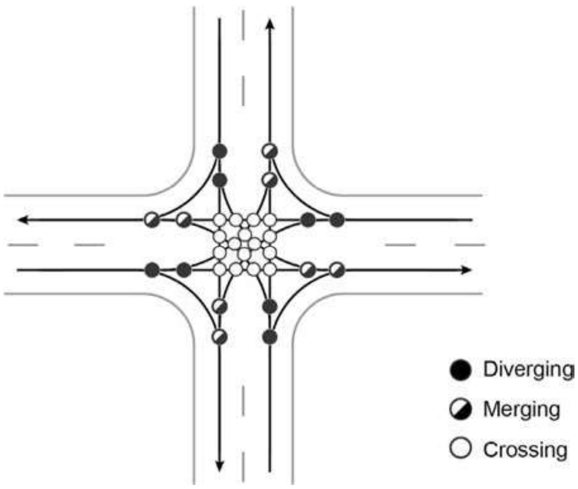
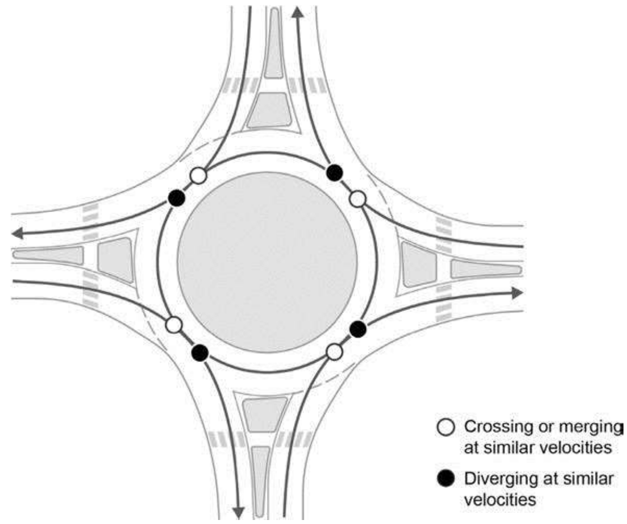


Figure 2. *A four-legged single-lane roundabout*



Other types of alternative intersections similarly have a reduced number of conflict points when compared to a traditional intersection. Even within a traditional intersection, the number and potential severity of conflicts can be reduced by restricting movements that can result in crossing conflicts, such as through or left-turn movements, or altering the geometry to reduce speeds.

Reducing vehicle speeds.

Reducing vehicle speeds increases reaction times for drivers and decreases the kinetic forces that are transferred in any crash. The survivability for pedestrians and bicyclists in particular is highly dependent on speed. Vehicle speeds can be reduced through roadway geometry and traffic calming measures, such as those shown in the Traffic Calming Guide.

Improving visibility at intersections.

Increasing sight distances at intersections, such as by removing parking, allows greater visibility between drivers, pedestrians, and other road users so that potential conflicts can be identified earlier. Adding lighting can increase nighttime visibility of users. Refer to the Caltrans Roadway Lighting Manual for lighting requirements.

Providing space and protection for pedestrians and bicyclists.

Physically separating transportation modes traveling at different speeds reduces conflicts. Dedicated facilities, such as sidewalks, can be provided for pedestrians, and bike lanes or separated bikeways can be provided for bicyclists. Separation can also be provided with respect to time at signalized intersections by implementing leading pedestrian intervals or pedestrian scramble phases. A pedestrian hybrid beacon similarly provides exclusive crossing time for pedestrians.

Process Considerations

Performance Measures

The performance measures associated with ISOAP differ from the prior ICE process in that the level of service (LOS) is no longer a primary influence because of updated areas of focus within the state, as noted in the Background section in this document. The performance measures for which intersections are measured are safety for all users, accommodating all users, and a measure of effectiveness (MOE) for throughput, such as daily person hours of delay (DPHD).

Applicability

ISOAP applies to new intersections or the major modification of existing intersections and local street interchanges (including to state conventional highways and expressways) on the State Highway System, including but not limited to the following:

- Connecting a new public road, private road, or high-volume (average daily traffic volumes of 1,000 or greater) driveway to a state highway or a new interchange to a freeway.
- Changing the type of traffic control, such as from stop-control to signal-control or from a two-way stop to all-way stop.
- Installing a pedestrian hybrid beacon at an intersection.
- Making major physical changes to intersection approaches, including at ramp terminals, such as adding a leg to an intersection or widening to provide an additional through or turn lane.

ISOAP does not apply to the following situations:

- Changes to lane configurations at existing intersections through modifications of signing or striping without any pavement widening.
- Minor modifications to existing traffic signals, such as adding or removing signal heads, upgrading signal poles that do not meet current standards, changing controller assemblies, adding signal priority, or modifying detection.
- Changes to controller software, signal phasing, or signal timing.
- Restricting movements at an existing intersection, such as prohibiting left turns or through movements.
- Installing warning devices, such as advance flashing beacons or rectangular rapid flashing beacons.
- Low-volume driveways in which turning restrictions are not deemed necessary by district Traffic Operations and Safety staff.

While ISOAP does not apply to restriping on existing pavement, including adding or removing lanes, those changes do require analysis for safety and operational impacts, such as queuing and traffic diversion. ISOAP may be applied if there are multiple alternatives.

Design Year

The design for new facilities and reconstruction should be based on the estimated traffic volumes 20 years following the completion of construction. With justification, a shorter design period may be approved by the District Director with concurrence by the Project Delivery Coordinator for projects off the Interstate Highway System. Refer to *Highway Design Manual* (*HDM)* Index 103.2 Design Period for additional information regarding the design period.

Roundabouts should be designed for 20-year traffic volumes but can initially be configured for 10 years and then expanded with minimal cost to the 20-year configuration. Refer to *HDM* Index 405.10 Roundabouts for additional information on the design period for roundabouts.

Process Flow Charts

ISOAP consists of two stages, including a Stage 1 Screening and Initial Assessment of viable strategies and a Stage 2 Detailed Assessment. ISOAP is intended to be scalable commensurate to the amount of analysis needed at a particular intersection and the level and quality of data available for a given project development stage. Early consultation with the community and local agencies is recommended to help stakeholders understand the ISOAP process, timelines, complexity, and expectations.

Stage 1 is typically done prior to or during the Project Initiation Document (PID) phase. For instance, if an improvement to an intersection is identified during a traffic investigation or local development review, then Stage 1 of ISOAP can be completed prior to the initiation of a project. If there are multiple potential buildable strategies, Stage 2 is typically done during the Project Approval and Environmental Document (PA&ED) phase, and the performance of various strategies is quantified with a benefit-cost ratio for improvements.

There are no prescribed tools in ISOAP other than the *Highway Safety Manual (HSM)* to be used in Stage 2 if applicable. Some of the typical tools are shown below. There are other tools available that can be used for evaluating the quality of service for pedestrians, bicyclists, and transit users.

Table 1. Typical Tools Used in ISOAP

ISOAP Stage	Typical Tools Used	Project Phase
Stage 1	CAP-X, Safety Performance for Intersection Control Evaluation (SPICE), Safe System Intersection methodology	Pre-PID, PID
Stage 2	Synchro/SimTraffic, Vistro/VISSIM, SIDRA, Rodel, Highway Capacity Software, *HSM*	PA&ED

Each stage of ISOAP is documented in the corresponding ISOAP form with appropriate supporting analysis and submitted to the District ISOAP Coordinator for approval, as detailed below.

For encroachment permits and projects funded by others, the project proponent is required to complete ISOAP for any applicable proposed modifications to existing intersections or for new major connections to state highways. ISOAP should be completed prior to submitting the encroachment permit application. Permit engineers and oversight project managers should assist with communicating the ISOAP process, resource impacts, and deliverable requirements during the initial consultation phase of a project.

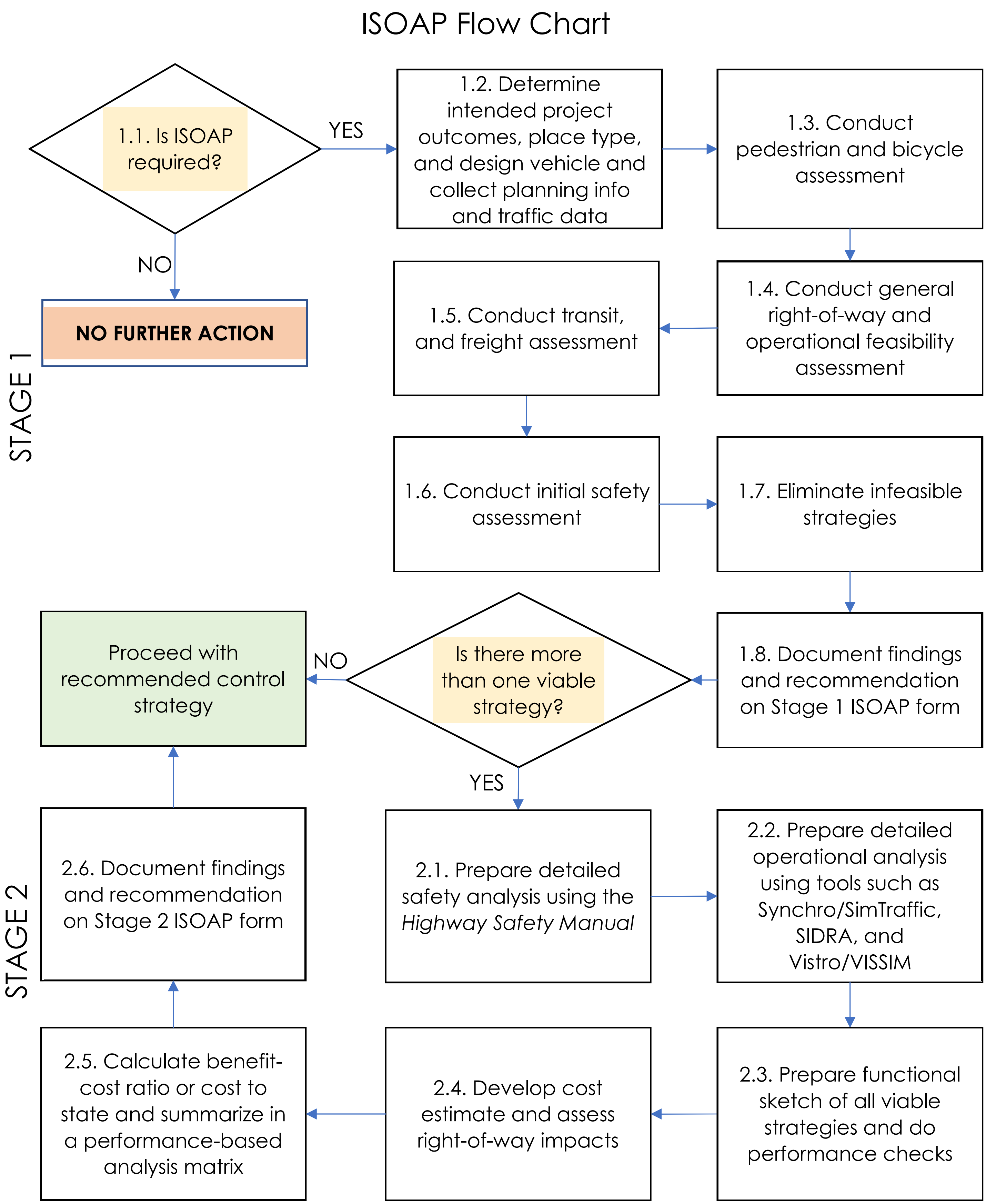
Streamlined Processes

The following situations will permit a streamlined ISOAP whereby alternative strategies need not be evaluated, and that ISOAP may conclude upon completion of Stage 1:

1. A new low-volume public road connection to a state highway in which signal warrants are not expected to be met during the 20-year design life. Alternative traffic control to a single stop sign at a T-intersection or a two-way stop at a four-legged intersection is not required unless the volume of pedestrians and/or bicyclists may merit additional controls or if the need for traffic calming may merit consideration of a roundabout.
2. A single-lane roundabout where the total of the average daily traffic for all approaches is less than 25,000 and signal warrants are projected to be satisfied within 10 years following project completion, or where there is a high number of broadside crashes, and the cost of a roundabout is comparable to signalization. If public concern is anticipated, evaluating alternative strategies may be required for the environmental process.

The ISOAP flow chart is shown in Figure 3.

Figure 3. ISOAP Flow Chart



Roles and Responsibilities

ISOAP may be performed by Caltrans staff or by others and then reviewed by Caltrans staff. The analysis may be performed by an individual or various members of a team. Coordination, technical support, and reviews are to be provided by Caltrans staff. As districts are organized differently, roles and responsibilities may vary by district. Below are the responsibilities of those involved in the analysis for ISOAP:

- **ISOAP Engineer** – The ISOAP Engineer performs the ISOAP in accordance with the ISOAP policy and associated guidance. The ISOAP Engineer considers appropriate access strategies, intersection control, and intersection configurations and consults with the District ISOAP Coordinator as needed. The ISOAP Engineer is to engage with functional units, such as Traffic Operations or Traffic Safety, as necessary for support and guidance for completing tasks.
- **Project Engineer** – The Project Engineer or Design Manager coordinates ISOAP process steps and activities when required for project initiation and/or project approval. The Project Engineer also develops geometrics for alternative strategies and cost estimates.
- **District ISOAP Coordinator** – Each district is to have a minimum of one designated District ISOAP Coordinator in a Traffic Operations functional unit to review ISOAP documents for adherence to guidance and to provide procedural and technical support. The District ISOAP Coordinator is to approve in writing each submittal of ISOAP Stages 1 or 2 unless a district has assigned that responsibility to another Traffic Operations functional manager. The District ISOAP Coordinator facilitates any exceptions to ISOAP with the Divisions of Traffic Operations and Safety Programs.
- **District Traffic Operations Engineer** – The District Traffic Operations Engineer performs, reviews, and provides guidance for operational analyses.
- **District Traffic Safety Engineer** – The District Traffic Safety Engineer provides guidance as needed for calculating the safety benefit and also reviews and concurs with the recommendations in ISOAP Stages 1 and 2.

The following are additional staff and teams involved in supporting ISOAP or project alternatives:

- **Project Development Team (PDT)** – The PDT selects the type of control and intersection configuration for State Transportation Improvement Program (STIP) and State Highway Operation and Protection Program (SHOPP) projects, as the PDT selects the preferred alternative for project approval. Decisions are documented in the Project Report or other approval document.
- **Local Development Review (LDR) Planner** – The District LDR planner coordinates reviews of local development proposals for impacts to the operation of state highways as well as reviews of local and regional transportation plans. The planners provide appropriate guidance to local agencies for future intersection

configurations, types of traffic control, and ISOAP with respect to potential improvements on state highways in coordination with the district Traffic Operations unit responsible for LDR.

- **Technical Planner** – The technical planner works with engineers to project future traffic volumes based on regional models for analyzing intersection configurations.
- **Complete Streets Coordinator** – The designated Complete Streets Coordinator in Planning and Modal Programs, Traffic Operations, or Asset Management is familiar with the Complete Streets needs for highways within their districts and plans SHOPP projects that may address these identified needs.
- **Permits Engineer** - For permit submittals through the Encroachment Permit Office Process, Encroachment Permits staff verify that ISOAP has been completed for any applicable changes to traffic control and that a Permit Engineering Evaluation Report (PEER) is completed.
- **Headquarters Traffic Operations** – Staff from the Transportation System Analysis Branch provides guidance, training, policy evaluation, technical support, and updates for ISOAP as required. Any exceptions to conducting ISOAP when applicability criteria are met will need to be approved by this branch.
- **Headquarters Safety Programs** – Staff from the Highway Safety Improvement Program (HSIP) Branch develop methodology and costs for calculating safety benefits to qualify for HSIP funding. Any exceptions to conducting ISOAP when applicability criteria are met will need to be approved by this branch.

Documentation and Forms

At the completion of each stage, the appropriate ISOAP form is to be completed and submitted with supporting documentation, such as functional sketches, cost estimates, and operational analysis, to the District ISOAP Coordinator or designated Traffic Operations functional manager for approval. Approved forms should be placed in the project development records. The ISOAP forms are contained within an Excel spreadsheet and are shown in Appendix B. The forms may be modified by the user to add control strategies or make other changes as needed.

Public Outreach

Stakeholder engagement is essential in developing transportation projects that support the needs and values of the communities in which they are located so that the intended project outcomes can be achieved. The project development process incorporates public outreach in the various phases of a project, and additional outreach specific to ISOAP should be strongly considered in most cases to ensure enough strategies are considered and analyzed in the appropriate context. Stakeholders need to be identified and could include intersection users, local agencies, transit agencies, school officials, landowners, nearby businesses, emergency responders, advocacy groups, trucking associations, farmers, and others as appropriate.

Local or regional transportation planning documents often include a public outreach process, but documents may become outdated or not reflect current policies, and additional outreach related to planning and land use may be needed.

Education may need to be provided to local officials or the public for novel or unfamiliar forms of intersections. The topics could include safety and operational characteristics, impacts to maintenance, and environmental and construction impacts.

Overview of Strategies

In this document, intersection configurations and control strategies will generally be called strategies. The strategies selected for analysis for a particular project may or may not correspond to project alternatives identified in project initiation, project approval, or environmental documents.

Strategies that may be considered for evaluation are shown and described in Appendix A.

At-Grade Intersections

At-grade intersections may be controlled with stop signs, yield signs (including at roundabouts), or traffic signals. Specific movements, often left turns, can be restricted or redirected to another intersection. Some examples of conventional intersections include the following:

- Minor road stop
- Minor road stop with turn restrictions (such as right in/right out, 3/4 movement)
- All-way stop
- Restricted crossing U-turn
- Median U-turn
- Displaced left-turn (partial or full)
- Bowtie
- Jughandle
- Thru-cut
- Quadrant
- Traffic signal
- Traffic signal with a continuous green T
- Pedestrian hybrid beacon
- Roundabout (mini, single-lane, hybrid, or multilane)

Grade Separations (Non-Interchange)

Partial grade separations are not common because of cost and right-of-way impacts, but they may be considered at high-volume intersections. Certain movements can be removed from the main intersection to reduce conflicts and provide more efficient signal phasing. Some examples of partial grade separations include the following:

- Jughandle
- Echelon intersection
- Center turn overpass

There are other possible configurations that can be used to separate certain movements. Grade separations may not be appropriate in certain urban environments, as the context needs to be considered.

Interchanges

Ramp terminal intersections at freeway interchanges can have similar types of controls as intersections at grade and are analyzed as such. Configurations that reduce the number of conflict points, especially crossing conflicts, reduce the potential for serious crashes. For instance, the partial cloverleaf interchange eliminates the left-turn movements to or from the on- or off-ramps. Particularly notable for their reduction of conflicting movements and cost-effectiveness are roundabout ramp terminal intersections and diverging diamond interchanges. More information on diverging diamond interchanges can be found in Design Information Bulletin (DIB) 90.

Stage 1 of ISOAP: Screening and Initial Assessment

Stage 1 of the ISOAP provides an initial screening of strategies so that detailed effort can be focused on the most viable strategies. The initial screening could reject strategies that have insurmountable environmental or right-of-way constraints. Strategies should also be appropriate to the context of the community in which the highway belongs.

The following are to be considered during the screening process:

- Excessive cost of improvements compared to the anticipated project budget should not in itself render any strategy nonviable, as improvements could potentially be planned or phased as funding becomes available.
- Lack of public support for a particular type of improvement is not a sufficient reason to reject a strategy.
- If there is not enough data or analysis conducted in Stage 1 to reject strategies, then the strategies are to be carried into Stage 2.
- If there is only one buildable strategy at the conclusion of Stage 1, then that strategy becomes the recommended strategy if it supports the intended project

outcomes and adequately addresses safety and operations, and ISOAP is completed for that project.

The following are the Stage 1 procedural steps as shown in Figure 3:

Step 1.1 Determine if ISOAP is required.

Use the applicability criteria provided in the Process Considerations section.

Any exception from conducting ISOAP for a proposed new or modified intersection meeting the applicability criteria will require approval from the Divisions of Traffic Operations and Safety Programs. The District ISOAP Coordinator will confer with the divisions to determine if the exception will be approved.

Step 1.2 Determine intended project outcomes, place type, and design vehicle, and then collect planning information and traffic data.

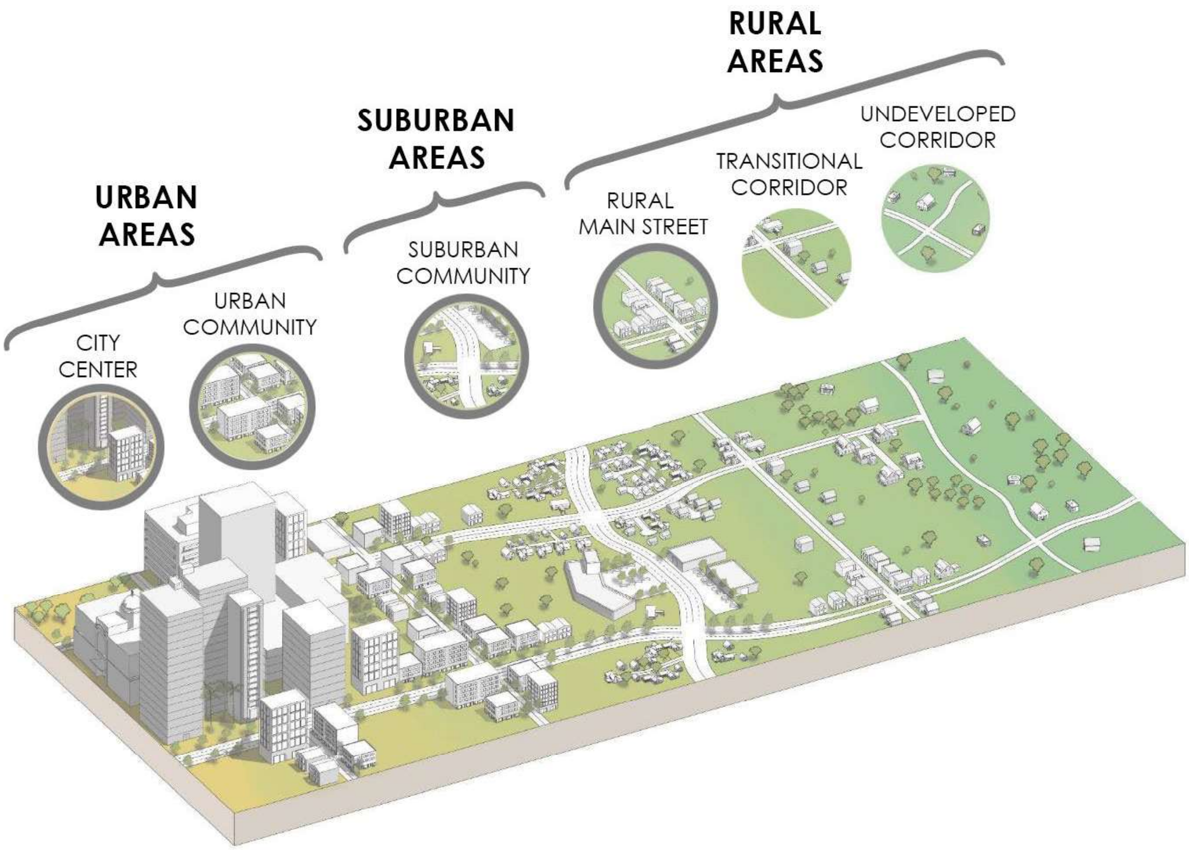
The intended project outcome is the desired result of a proposed project. For example, the intended project outcome may address a safety or operational deficiency, increase throughput for a particular mode, improve livability by calming traffic, or address transportation disparities. It is possible that the performance for some metrics may decrease over the current condition. For instance, a project to implement a road diet may result in additional delay and queuing but improve the quality of service for other modes, such as walking and biking, which may be more difficult to quantify. The intended project outcomes should be a collaborative effort with other functional units and project stakeholders.

The place type is the character, size, and density of the community. The place type should be based on existing and proposed land use. Additional information on place types can be found in *HDM* Index 81.3 Place Types and the *Smart Mobility 2010: A Call to Action for the New Decade*.

Caltrans uses the following designations for place types:

- Urban areas
    - Center cities
    - Urban communities
- Suburban areas
- Rural areas
    - Rural main streets
    - Transitional corridors
    - Undeveloped corridors
- Special use areas and protected lands

Figure 4. Place Types for Contextual Design Guidance (Source: *HDM* Index 81.3)



Refer to *HDM* Index 81.3 Place Types for information regarding the characteristics of the various place types. In general, the urban place types place stronger emphasis on pedestrians, bicycles, and transit.

An appropriate design vehicle needs to be selected based upon the type of truck network to which a route belongs. The Surface Transportation Assistance Act (STAA) truck should be the typical design vehicle, but a lesser design vehicle may be used with the concurrence of the District Truck Access Manager (DTAM) and with appropriate justification and documentation. Refer to *HDM* Topic 404 Design Vehicles for additional information.

Available system planning information are to be gathered, including Transportation Concept Reports, Comprehensive Multimodal Corridor Plans, Active Transportation Plans, and local agency planning documents. Available traffic counts (such as vehicle, truck, turning movement, pedestrian, and bicycle), existing roadway configuration, right-of-way, and collision data should also be gathered.

Step 1.3 Conduct pedestrian and bicyclist planning and feasibility assessment.

Pedestrians and bicyclists could potentially cross at any intersection on the State Highway System. DP-37 on Complete Streets states that "Accordingly, in locations with current and/or future pedestrian, bicycle, or transit needs, all transportation projects funded or overseen by Caltrans will provide comfortable, convenient, and connected complete streets facilities for people walking, biking, and taking transit or passenger rail unless an exception is documented and approved." Caltrans strives to serve users of all ages and abilities and use design flexibility to provide context-sensitive solutions. The needs of visually impaired pedestrians are also to be considered.

The existing and planned land use near an intersection should be considered in determining the type of pedestrian route or bikeway. Of particular interest are where schools and residences are on opposite sides of the intersection. As examples of how pedestrians may be considered, a project near senior housing may need to have longer pedestrian crossing times, and pedestrian scramble phasing may be appropriate at a traffic signal near a school.

Caltrans has developed extensive Complete Streets tools and guidance that can be used for developing appropriate pedestrian and bicycling facilities for the place type. The Complete Streets Toolbox and other resources can be accessed from the Division of Transportation Planning Complete Streets website.

Additional resources regarding place type include the following:

- Improving Intersections for Pedestrians and Bicyclists Informational Guide (FHWA, 2022) provides assessment techniques for various types of intersection configurations and design features and countermeasures that can be used to enhance pedestrian and bicyclist safety.
- FHWA Bikeway Selection Guide (2019).
- National Cooperative Highway Research Program (NCHRP) Report 948, Guide for Pedestrians and Bicyclist Safety at Alternative and Other Intersections and Interchanges (2021).
- NCHRP Report 834, Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities: A Guidebook (2017).
- NCHRP Report 1043, Guide for Roundabouts (2023).
- Supplement to the Application of the Highway Safety Manual Methodology for DIB 94 Eligible Projects Caltrans, 2024) for conducting a safety analysis and informing engineering judgment and discretion when balancing roadway cross-section elements for DIB 94 projects.

Step 1.4 Conduct general right-of-way and operational feasibility assessment.

Footprints for potential improvements are based on typical designs. The number of lanes can be determined by using the Capacity Analysis for Planning of Junctions (CAP-X) Tool developed by FHWA. The tool is based on an Excel spreadsheet and determines the volume-to-capacity ratio and multimodal accommodations for various intersection configurations.

The Virginia Department of Transportation has developed a tool, the Virginia Junction Screening Tool, or VJust, that may also be used to analyze various types of innovative intersections.

More advanced tools such as Synchro for signalized intersections or SIDRA for roundabouts may be used, but that level of detail is not expected until Stage 2 of ISOAP as support resources are typically limited during the PID phase. Sizing an intersection to meet a particular level of service threshold should not be a primary objective. As LOS is no longer the standard performance metric, the MOE should be documented. This may be DPHD, volume/capacity ratio, queuing, or another measure as directed by the District Traffic Operations Engineer.

The concepts developed during Stage 1 should be considered conceptual, as the more detailed operational analysis would typically be completed during Stage 2. However, if detailed operational analysis is needed before eliminating strategies, strategies should be carried over to Stage 2 unless the detailed analysis can be conducted in Stage 1.

An optional worksheet showing possible control access strategies is provided with the ISOAP forms and can be used to help select appropriate strategies.

Standard geometrics in the *HDM* and DIB 94 should be used in determining intersection footprints, including appropriate sizing of roundabouts. The footprint for a roundabout should include the proposed pedestrian route and bikeway. Roundabouts must be able to accommodate the appropriate design vehicle. Refer to Stage 1, Step 1.5 for guidance on how to accommodate freight. *HDM* Chapter 400, Index 405.10 Roundabouts provides guidance for geometric features and performance checks for roundabouts. Performance checks can be deferred to Stage 2 of ISOAP unless the viability of the roundabout is highly dependent on a precise footprint.

Where an intersection is near at-grade railroad tracks, operational impacts of a passing train will need to be evaluated to address queuing and the need for pre-signal systems.

In evaluating intersection footprints, known constraints such as environmentally sensitive areas and costly right-of-way should be noted and avoided. However, the need to acquire right-of-way or conduct additional environmental analysis should not in itself be considered constraints. Access management needs should be considered, as closing or consolidating access points and constructing channelization may have significant cost.

For proposed projects that satisfy the streamlined criteria applicable for stop control on minor legs and roundabouts for lower-volume intersections, as discussed in the Process Considerations section of this document, alternate strategies do not need to be considered for ISOAP and the remaining steps for Stage 1 are to be completed without a need to proceed to Stage 2.

Step 1.5 Conduct transit and freight assessment.

Proposed intersection designs need to accommodate buses, streetcars, and other modes of public transit as applicable. Vehicle turning templates, transit vehicle queuing, passenger queuing, transit shelters, and appropriate near side or far side placement of transit stops need to be considered. Intersections are often the transfer location of different transit routes, in which transit vehicles may park for extended periods and necessitate extended bus bays. Throughput for transit can be increased with transit-only lanes or transit signal priority.

Trucks do not necessarily need to be accommodated for all movements at an intersection, as the land use accessed by each leg of an intersection should be considered. The needs of oversize vehicles should also be assessed. Some routes may need to accommodate certain types of large agricultural equipment or other oversize loads, and the design vehicle may be a type of booster truck as specified in the *HDM*. The frequency of such loads and availability of alternate routes should also be considered. The DTAM should be consulted for appropriate truck accommodation.

Step 1.6 Conduct initial safety assessment.

The relative safety of the various potential strategies should be considered to compare with the existing condition of the intersection. The SPICE tool, Caltrans Traffic Accident Surveillance and Analysis System rate groups, crash modification factors, or other methods may be used. The SPICE tool was developed by FHWA and is an Excel spreadsheet tool that performs a predictive safety analysis for at-grade intersections of various types of control, when applicable, and is based on the *HSM* methodologies. Crash modification factors are derived from studies and measure the crash reduction potential of various types of safety improvements and can be used for a qualitative analysis.

The Safe System for Intersections (SSI) methodology developed by FHWA analyzes intersection strategies by incorporating conflict point identification and exposure, kinetic energy transfer, and intersection movement complexity to produce a score that characterizes the extent that the strategy aligns with the Safe System framework. A qualitative assessment using Safe System Approach principles detailed in the Safe System Approach section of this document can also be conducted to help eliminate infeasible strategies if deferring the quantitative safety assessment to Stage 2.

If SSI methodology cannot be employed in its entirety, a general analysis of conflict points, applicable vehicle speed reduction measures, and visibility enhancements can also be used.

Step 1.7 Eliminate infeasible strategies.

It is sufficient to reject strategies that do not satisfy the intended project outcomes, have environmental impacts that cannot be reasonably mitigated, do not adequately address road user safety performance for both crash severity and frequency, or have costs that exceed available and potentially available funding for improvements.

Step 1.8 Document findings and recommendation.

If there is more than one viable strategy, then the recommendation would be to proceed to Stage 2 of ISOAP. The most viable or highest performing strategies should be carried forward to Stage 2 if a large number of strategies remain. If there is only one viable strategy that has improved performance over the current condition, then that would become the recommended strategy.

For capital projects, if there is only one viable strategy and if the available funding is insufficient for the recommended strategy, the following potential funding sources should be considered:

- Combining with planned SHOPP work, such as rehabilitation.
- SHOPP safety funding if an existing safety deficiency has been identified.
- Congestion Mitigation and Air Quality Improvement Program (CMAQ).
- Local Highway Safety Improvement Program (HSIP).
- Active Transportation Program (ATP) grant funding.
- Minor A or B funding for components with independent utility.
- Regional Transportation Improvement Program (RTIP).
- Developer fees or mitigation.
- Local transportation sales tax measures.

The district Traffic Operations functional units, Asset Management, and district Planning division should be consulted on the potential availability of such funding.

A phased implementation of the recommended strategy could also be considered, as well as cost-effective interim improvements not necessarily compatible with future improvements.

The recommendation is documented on the completed Stage 1 ISOAP form and submitted to the district ISOAP Coordinator with applicable analysis and assessment files for review and approval by the designated Traffic Operations functional manager. One form is to be submitted for each analyzed intersection. If there is only one proposed strategy, the District Traffic Safety Engineer is to review and concur with the recommendation.

All viable strategies should be noted in the PID. For capital projects and projects that require an encroachment permit, refer to Project Development Procedures Manual (PDPM) Chapter 9, Project Initiation for further information on PIDs. For encroachment permits in which a Project Report or Design Engineering Evaluation Report (DEER) is not required, decisions are documented in the Permit Engineering Evaluation Report (PEER).

Stage 2 of ISOAP: Detailed Analysis

If more than one buildable strategy remains after Stage 1 of the ISOAP, the strategies proceed to Stage 2 for more detailed analysis.

Step 2.1 Prepare a detailed safety analysis.

A quantitative safety analysis is performed to show predicted crash frequency and severity for each strategy. The *HSM* is to be used where applicable. By utilizing Caltrans' crash costs, the predicted crashes and their severities are converted into a dollar amount that can be used in an economic analysis to determine a benefit-cost ratio or an overall cost to the state for each strategy. Note that a Stage 2 quantitative safety analysis and a Stage 1 SPICE tool analysis may result in different crash performances. The tools and methodologies described in Stage 1, Step 1.6 can also be used if the quantitative safety assessment was deferred to Stage 2.

For more information on applying the *HSM*, see the Caltrans Highway Safety Manual website.

Where the *HSM* cannot be used, a qualitative safety analysis may be performed. Although a thorough economic analysis of a strategy's safety outcomes cannot be utilized with a qualitative analysis, a general statement of the safety benefits can be provided using a specific countermeasure or crash modification factor, treatment, or strategy.

Step 2.2 Prepare a detailed operational analysis.

Intersection operational analysis tools include the following software:

- Synchro/SimTraffic
- Highway Capacity Software
- Vistro/VISSIM
- SIDRA
- Rodel
- Other less common software, such as TransModeler

Synchro/SimTraffic or other similar signal analysis software should be used for any proposed new or modified traffic signals. While Rodel can be used to analyze roundabouts, SIDRA is the preferred tool for analyzing roundabouts (Caltrans Recommended Settings and Standards for SIDRA [internal only]). For more complex intersections, networks, and innovative designs, such as turbo roundabouts, Vistro/VISSIM or other microsimulation software should be used. Analysis tool selection is dependent on project area, strategy type, complexity, and is subject to approval by the District Traffic Operations Engineer.

Operational analysis and associated transportation analysis should include the following:

- A study area that is large enough to capture all potential impacted facilities.
- Data collected during appropriate times of day, days of the week, and times of year.
- Analysis of multiple time periods may be needed to adequately assess project strategy performance.
- Data collection should include pedestrians, bicyclists, transit, and freight movements.
- Proper model calibration to existing conditions including volume and queuing calibration.
- Best practice travel forecasting methodologies, including the use of travel demand models to forecast volumes for each analysis scenario.

As LOS is no longer the standard performance metric, the MOE should be documented and may be DPHD, volume/capacity ratio, queuing, or other measure as directed by the District Traffic Operations Engineer. The operational analysis should address accommodation of queues. The summarized traffic analysis should be included in the project Traffic Operations Analysis Report (TOAR).

Quality of service for pedestrians, bicyclists, and transit users is also to be considered.

Step 2.3 Prepare functional sketches of feasible strategies and do performance checks.

A conceptual layout should be prepared for each feasible strategy based upon the number of required lanes identified by the operational analysis. The layout should show pedestrian and bicycle facilities and transit stops within the project limits. The level of detail should be sufficient to develop a cost estimate and evaluate right-of-way and potential environmental impacts. To avoid unreasonable disruptions to road users, drainage and utilities need to be considered, including the locations of maintenance access points. This work is typically done for alternatives during PA&ED and therefore would not require additional work in the project development process.

Geometric performance checks for roundabouts, including for fastest path, should be done. All intersections should be reviewed for geometric adequacy, such as having sufficient sight distance. DIB 90, Diverging Diamond Interchanges, can be used for performance checks for diverging diamond interchanges.

NCHRP Report 948, Guide for Pedestrians and Bicyclist Safety at Alternative and Other Intersections and Interchanges has a design flag assessment that can be used to evaluate pedestrian and bicycle safety, accessibility, comfort, and operational aspects across an intersection.

Step 2.4 Develop a cost estimate and assess right-of-way impacts

A cost estimate for construction and right-of-way should be developed for each viable strategy. The Project Engineer typically develops the cost estimate with input from various function units. Costs for rearranging drainage inlets and culverts, utilities, and maintenance access points determined in step 2.3 can be significant if the roadbed is widened or a median island is proposed. Cost for traffic handling can also be significant if there are multiple stages of intersection construction, construction of a detour, or extended working days. Annual maintenance costs, including electricity and other periodic maintenance costs, can also be used for calculating life-cycle costs. Crash costs are also calculated, where applicable. NCHRP Document 220 Estimating the Life-Cycle Cost of Intersection Designs may be used as a tool to estimate life-cycle costs.

Step 2.5 Prepare a performance-based analysis matrix.

Use the matrix provided on the Stage 2 ISOAP form to compare the operational and safety performance, life-cycle cost estimate, and benefit-cost ratio for each viable strategy. For construction of new facilities, the cost to the state, which is the sum of all the project costs (construction, right-of-way, environmental, and maintenance) and costs to the traveling public (crashes and delay over the life of the project) may be used as an alternative to the benefit-cost ratio.

Step 2.6 Document findings and recommendation.

The highest performing strategy that is consistent with the project type and project-specific context, and that supports the principles of the Safe System Approach, becomes the recommended strategy. The recommended strategy may or may not be the strategy with the highest benefit-cost ratio. There may also be considerations regarding equity that could favor a strategy that better serves a disadvantaged community. Bicyclist and pedestrian accommodations are documented in the recommendation as well as a description as to how the recommended strategy supports the Safe System Approach.

The selected strategy should incorporate features that make it maintainable and reduce exposure to field personnel. Some strategies may not be compatible with snow conditions.

As mentioned in Step 1.8, the cost for a recommended strategy may exceed the available funding for a project. Additional funding sources and phased implementation should be considered in such situations.

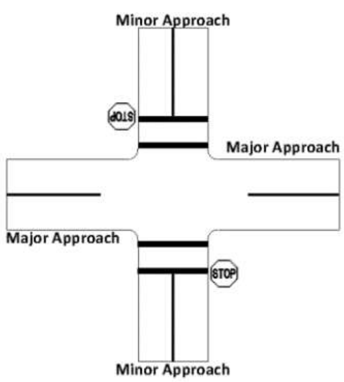
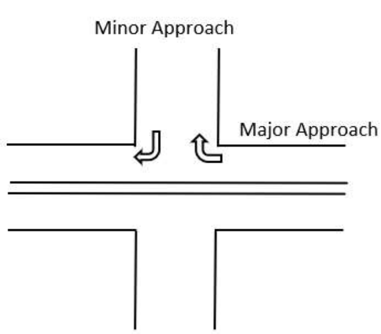
The completed Stage 2 ISOAP form is submitted to the District ISOAP Coordinator with applicable analysis and assessment files for review and approval by the designated Traffic Operations functional manager. The District Traffic Safety Engineer also reviews and concurs with the recommendation.

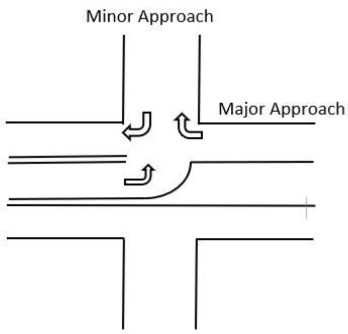
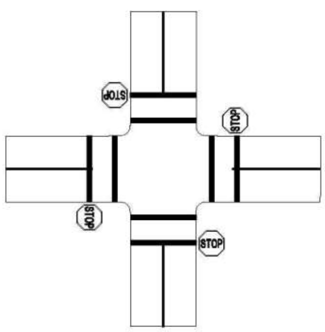
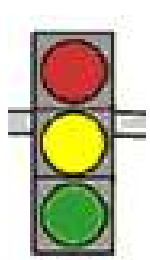
For capital projects, the PDT selects the type of traffic control or intersection configuration, and the decisions are documented in the Project Report. For projects funded by others that are subject to the Quality Management Assessment Process (QMAP), decisions are documented in the Project Report. For capital projects and projects that require an encroachment permit, refer to PDPM Chapter 9, Project Initiation.

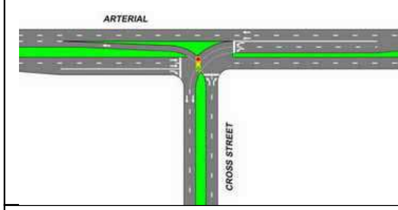
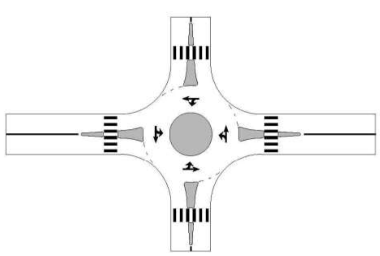
Appendix A: Intersection Types and Control Strategies

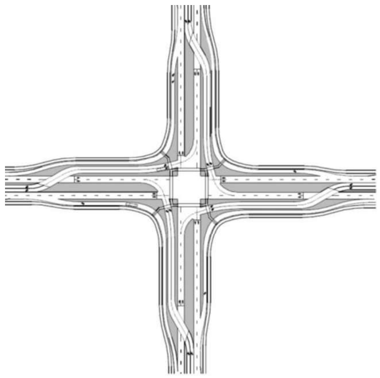
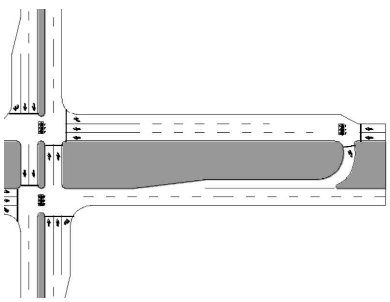
The following table highlights conventional and innovative intersection strategies touched upon within this document. This table is not all-inclusive, and additional innovative intersection strategies that serve the intended project outcomes and meet the DPHD outlined in the Process Considerations section of this document are encouraged.

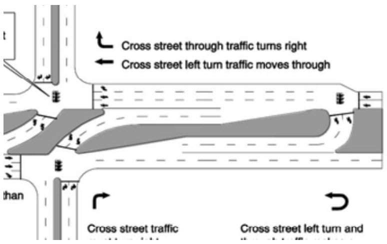
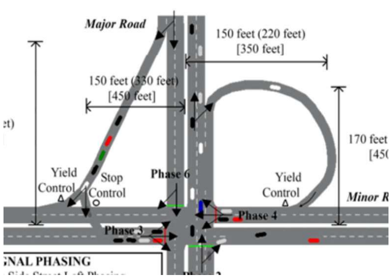
Table 2. Intersection Types and Control Strategies

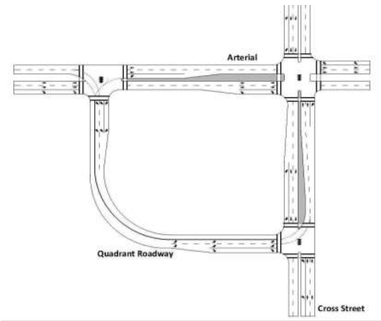
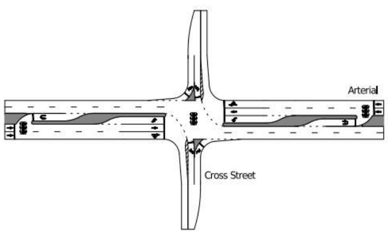
Type of Intersection Control	Description	Pedestrian Accommodation	Bicyclist Accommodation
<u>Minor Road Only Stop</u>  	Traffic on the minor approach stops for the major approaches.	Pedestrian facilities are typically provided in an urban or urbanizing area or rural main street. In accordance with DP-37, pedestrian facilities should also be considered in other contexts. High visibility crosswalks, rectangular rapid flashing beacons, pedestrian hybrid beacons, and curb extensions (built outs) are potential enhancements for crossings at the major approaches.	Class II bike lanes, Class IV separated bikeways, or striped shoulders can be placed on the major approaches.
<u>Right-In/Right-Out</u>  	This variant of a minor road only stop restricts left turns into or out of a minor road, usually by the placement of a raised median.	Same as Minor Road Only Stop above.	Class II bike lanes, Class IV separated bikeways, or striped shoulders can be placed on the major approaches.

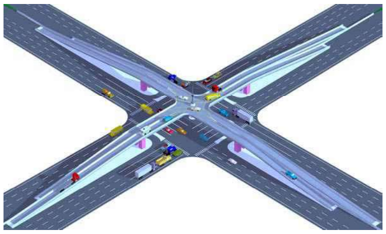
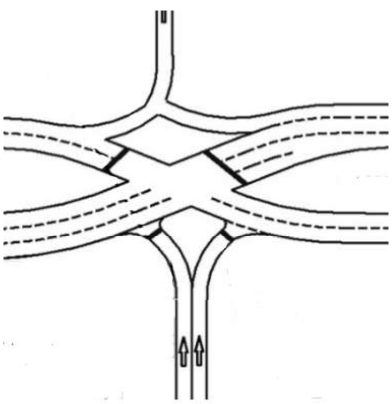
Type of Intersection Control	Description	Pedestrian Accommodation	Bicyclist Accommodation
<u>3/4 Movement</u> 	This variant of a minor road only stop restricts left turns from the minor road, usually by the placement of a traffic diverter (also known as a "worm").	Same as Minor Road Only Stop above.	Class II bike lanes, Class IV separated bikeways, or striped shoulders can be placed on the major approaches.
<u>All-Way Stop</u> 	All legs into an intersection are required to stop. An all-way stop has limited capacity and works better when the legs have balanced volumes.	Pedestrian facilities are typically provided in an urban or urbanizing area or on a rural main street. In accordance with DP-37, pedestrian facilities should also be considered in other contexts. Curb extensions are potential enhancements.	Class II bike lanes, Class IV separated bikeways, or striped shoulders can be placed on the major approaches.
<u>Signalized Intersection</u> 	The traffic signal is best suited for high traffic volumes or where right-of-way is constrained. The cost for signalization is highly dependent on the amount of roadwork needed and can range between $400,000 to $2 million or more.	Pedestrian signals are placed at designated crosswalks. Leading pedestrian intervals and pedestrian scramble phases can enhance the pedestrian crossings.	Bicyclists follow the vehicular signal indications. Bicycle signals can be used in conjunction with a Class IV separated bikeway. Protected intersection features can reduce conflicts with vehicles turning right.

Type of Intersection Control	Description	Pedestrian Accommodation	Bicyclist Accommodation
Continuous Green T (YouTube)  	This variation of signalized intersection, typically at a rural location, provides a continuous free through movement for the top of the T.	Typically, no pedestrian accommodations are provided to cross the major street.	Bicyclists follow the vehicular signal indications.
Pedestrian Hybrid Beacon (YouTube) 	A pedestrian hybrid beacon provides positive control to give right-of-way to pedestrians crossing a major street. Warrants for a pedestrian hybrid beacon have lower volume thresholds than for a traffic signal, and there is less disruption to traffic flow as compared to a traffic signal. A pedestrian hybrid beacon costs slightly less than a typical signal, ranging between $300,000 to $1.5 million.	The pedestrian experience at a pedestrian hybrid beacon is similar to that of a traffic signal.	Bicyclists can utilize a pedestrian hybrid beacon the same as pedestrians.
Roundabout (YouTube) 	All approaches have yield control, and splitter islands reduce speeds of approaching vehicles. The cost of a roundabout can vary from $500,000 for a temporary roundabout with minimal pavement and concrete work to $10 million or more for a multilane roundabout.	Crosswalks can be provided across all approaches of a roundabout as needed. Crossings at multilane approaches may be enhanced with the placement of rectangular rapid flashing beacons.	Bicyclists may travel through the roundabout with vehicles or on a shared used path, if provided.

Type of Intersection Control	Description	Pedestrian Accommodation	Bicyclist Accommodation
Displaced Left-Turn Intersection (YouTube) 	Left turns are relocated to the opposing side of approaching traffic with an upstream traffic signal. The main intersection is a two-phase signal. A large footprint is required. No displaced left-turn intersections are currently in California.	Multiple signalized crossings are needed to cross the legs.	Bicyclists can use a shared use path, if provided.
Median U-Turn (YouTube) 	Left turns are prohibited on both the major and minor streets and facilitated by having a U-turn movement on only the major street downstream of the intersection. This configuration is for signalized intersections, results in some out-of-direction travel, and is typically used where there is a wide center median. At narrower medians, the U-turn movement can be accommodated by using a loon to allow large vehicles turn.	Crossings are signalized and can have two stages across the major street.	Separated bikeways, shared use path, and/or bike boxes can be placed to accommodate bicyclists making left turns at the intersection.

Type of Intersection Control	Description	Pedestrian Accommodation	Bicyclist Accommodation
Restricted Crossing U-Turn  	Through and left-turn movements are prohibited from the minor street. The movements are accommodated with a U-turn movement downstream of the intersection, necessitating some out-of-direction travel. Restricted crossing U-turns can be signalized or unsignalized and are typically on expressway-type facilities.	Restricted crossing U-turns are typically in rural environments and do not have controlled crossing. A crosswalk can be placed through the median.	Bicyclists can be facilitated by having a cut-through in the median.
Jughandle (YouTube)  	Left turns are removed from the major street and redirected to the minor street with either a diamond-style ramp or loop downstream of the intersection. A large footprint may be needed to accommodate all movements, and there is out-of-direction travel for some turning movements.	Pedestrians are accommodated similarly to a conventional signalized intersection.	Bicyclists are accommodated similarly to a conventional signalized intersection.

Type of Intersection Control	Description	Pedestrian Accommodation	Bicyclist Accommodation
Quadrant Roadway (YouTube) 	All left-turn movements are eliminated at the main intersection and re-routed through a connector roadway at one quadrant of the intersection. Out-of-direction travel is required for some turning movements.	Pedestrians use conventional signalized crosswalks.	For left turns, bicyclists can use a bike box or shared use path, if provided.
Thru-Cut (YouTube) 	Through movements are prohibited from the minor street and are accommodated by making a right or left turn and then turning at the next street or by making a U-turn on the major street to travel back to the intersection to make a right turn. Thru-cuts are generally signalized.	At a signalized thru-cut, pedestrians use conventional signalized crosswalks.	At a signalized thru-cut, bicyclists may use a signalized crosswalk to cross the major street.
Echelon (YouTube) 	One approach of each street is elevated, and the result is two one-way signals with efficient two-phase operation.	Pedestrian facilities are provided along the at-grade portion of the intersection.	Bike lanes can be provided for all legs of the intersection. A shared use path can also be provided along the at-grade portion of the intersection.

Type of Intersection Control	Description	Pedestrian Accommodation	Bicyclist Accommodation
Center Turn Overpass 	The left-turn movements ascend to an elevated portion of the intersection controlled with a two-phase signal with left-turn only movements. The main portion of the intersection also operates with two phases.	Pedestrian facilities are provided along the at-grade portion of the intersection.	Bike lanes can be provided for all legs of the intersection. A shared use path can also be provided along the at-grade portion of the intersection.
Diverging Diamond Interchange (YouTube) 	The diverging diamond interchange is a high-capacity interchange design that can be cost-effective to implement for an existing diamond interchange. The signals have efficient two-phase operation. Cost can range between $20 million to $30 million for retrofitting a diamond interchange.	Either median or outer walkways can be provided. Either configuration requires four crossings of traveled ways. A grade separated shared used path can also be provided and would eliminate all vehicular crossings but would increase the distance that a pedestrian would need to travel.	Bicyclists can be accommodated in bike lanes, and the pedestrian walkways can be designed as shared use paths.

Appendix B: ISOAP Forms

The ISOAP forms below can be found on the Caltrans Intersection Safety and Operational Assessment Process web page.

Stage 1 of ISOAP: Screening and Preliminary Assessment						
Prepared by:				Date		
Cty-Rte-PM				Project EA		
Major Street		Speed Limit		ADT	Existing	
					Future	
Minor Street		Speed Limit		ADT	Existing	
					Future	
Place Type				Design Vehicle		

Project Description (scope, intended project outcome, etc.)	
Existing Conditions (intersection configuration and surrounding land use):	
Multimodal Context (describe pedestrian, bicycle, and transit activity in area)	

Strategy Feasibility (for each strategy considered, provide a summary of initial safety and operational assessments, accommodations of pedestrians and bicyclists, and/or constraints, note any impacts to transit or freight; add rows as needed for additional strategies):	
Strategy 1	
Strategy 2	
Strategy 3	
Strategy 4	

Rejected Strategies (describe any notable strategies that satisfy the Safe System Approach but were rejected):

Recommendation (discuss if there is a need to proceed to Stage 2 and with which strategies):

Include attachments as needed.

Stage 1 Control Strategy Worksheet (Optional)					
Prepared by:				Date	
Cty-Rte-PM				Project EA	
Major Street		Existing AADT		Speed Limit	
Minor Street		Existing AADT		Speed Limit	

Control Strategy	**Is it a viable strategy? (Y/N)**	Meets intended project outcomes (Y/N)	Warrants met (if applicable) (Y/N)	Performs acceptably (Y/N)	Addresses peds and bikes (Y/N)	Acceptable impacts to R/W and env. (Y/N)
Minor Road Stop						
Right In/Right Out						
3/4 Movements						
All-Way Stop						
Traffic Signal						
Continuous Tee Signal						
PHB						
Roundabout						
Displaced Left-Turn						
Median U-Turn						
RCUT						
Jughandle						
Quadrant Roadway						
Thru-Cut						
Echelon						
Center Turn Overpass						
DDI						

Stage 2 of ISOAP: Detailed Engineering Assessment						
Prepared by:				Date		
Cty-Rte-PM				Project EA		
Major Street		Speed Limit		ADT	Existing	
					Future	
Minor Street		Speed Limit		ADT	Existing	
					Future	
Place Type				Design Vehicle		

Project Description (scope, need and purpose, etc.)	
Future Conditions (surrounding land use):	
Future Multimodal Context (describe future pedestrian, bicycle, and transit activity in area)	

Operational Analysis Summary (for each viable strategy, describe performance and measure of effectiveness, such as daily person hour delay, or volume to capacity ratio, and queue accommodation):	
Strategy 1	
Strategy 2	
Strategy 3	
Strategy 4	

Safety Performance (predicted crashes):	
Strategy 1	
Strategy 2	
Strategy 3	
Strategy 4	

Performance-Based Analysis Matrix (include operational and safety performance, life-cycle cost estimate, and benefit-cost ratio or Cost to State for new facilities):

	Capital Cost	Service Life	Delay Cost	Collision Cost	Maint Cost	Life-Cycle Cost	Benefit/ Cost
Strategy 1							
Strategy 2							
Strategy 3							
Strategy 4							

Recommendation (describe recommended strategy including discussion of accommodations for bicyclists and pedestrians and how it supports the Safe System Approach):

Include attachments as needed.

Appendix C: Abbreviations

CAP-X – Capacity Analysis for Planning of Junctions

DEER – Design Engineering Evaluation Report

DIB – Design Information Bulletin

DP – Director's Policy

DPHD – Daily Person Hours of Delay

FHWA – Federal Highway Administration

HDM – Highway Design Manual

HSM – Highway Safety Manual

ICE – Intersection Control Evaluation

ISOAP – Intersection Safety and Operational Assessment Process

LDR – Local Development Review

LOS – Level of Service

MOE – Measure of Effectiveness

NCHRP – National Cooperative Highway Research Program

PA&ED – Project Approval and Environmental Document

PDPM – Project Development Procedures Manual

PEER – Permit Engineering Evaluation Report

PDT – Project Development Team

PID – Project Initiation Document

QMAP – Quality Management Assessment Process

SHOPP – State Highway Operation and Protection Program

SHSP – Strategic Highway Safety Plan

SPICE – Safety Performance for Intersection Control Evaluation

SSI – Safe System for Intersections

STAA – Surface Transportation Assistance Act

TOPD – Traffic Operations Policy Directive