Application of the Highway Safety Manual Methodology for Project Development

California Department of Transportation

Division of Design

March 30, 2023

This Highway Safety Manual is neither intended as, nor does it establish, a legal standard for the concepts, guidelines, and computational procedures for predicting safety performance of various highway facilities. The guidelines discussed herein for the information and guidance of the officers and employees of the Department. It is not intended that any standard of conduct or duty toward the public shall be created or imposed by the publication of this manual. This Manual is subject to the provisions of 23 U.S.C. § 407, which provides reports, surveys, schedules, lists, or data compiled or collected for the purpose of identifying, evaluating, or planning the safety enhancement of potential accident sites, hazardous roadway conditions, or for the purpose of developing any highway safety construction improvement project which may be implemented, shall not be the subject to discovery or admitted into evidence in a Federal or State court proceeding or considered for other purposes in any action for damages arising from any occurrence at a location mentioned or addressed. (23 U.S.C. § 407)

This manual is not a textbook or a substitute for engineering knowledge, experience, or judgment.

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Chapter 1: Introduction

The American Association of State Highway Transportation Officials (AASHTO) published the Highway Safety Manual (HSM) to provide concepts, guidelines, and procedures for predicting the safety performance of various highway facilities. The HSM is neither intended as, nor does it establish, a legal standard for the concepts, guidelines, and computational procedures for predicting safety performance of various highway facilities. The guidelines discussed herein for the information and guidance of the officers and employees of the Department. It is not intended that any standard of conduct or duty toward the public shall be created or imposed by the publication of this manual.

This manual is not a textbook or a substitute for engineering knowledge, experience, or judgment.

The HSM consists of 3 volumes published in 2010 and a supplement published in 2014. It is divided into four parts:

Part A – Introduction, Human Factors, Fundamentals of Safety

Part B – Roadway Safety Management Process

Part C – Predictive Methods; and

Part D – Crash Modification Factors

Applicable portions of Part A and B principles and best practices have been incorporated into this guidance. Part C contains the predictive methods to estimate collision frequencies based on different operational and geometric features. Part D and the HSM Crash Modification Factor (CMF) Clearinghouse may be needed to supplement the Part C methods. To use the HSM for development of projects on the State Highway System, this document presumes the reader has been trained in the use of HSM Part C methods and Part D CMFs. Throughout this guidance, the use of the terms “collision methods,” “collision severities,” or “collisions” is based on the statistically modeled “predicted” outcomes.

For information on the HSM see AASHTO’s HSM website[1] and for more information on HSM tools, including the Part C tools, see AASHTO’s HSM Tools website[2].

1.1 Caltrans and Implementation of the Highway Safety Manual

The California Department of Transportation (Caltrans) issued a “Performance-based Decision-making using the Highway Safety Manual” memorandum on April 4, 2022 (Memo), attached as Appendix A, which outlines project application requirements during the Project Approval and Environmental Document (PA&ED) and Plans, Specifications, and Estimate (PS&E) phases. The Memo also provides information on roles and responsibilities, analysis, and limitations of using HSM. The HSM as a proactive safety

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[1] http://www.highwaysafetymanual.org/Pages/default.aspx

[2] http://www.highwaysafetymanual.org/Pages/Tools.aspx

analysis tool supports Caltrans' Director's Policy 36: "Road Safety" and the Safe System approach[3].

The HSM can be used to analyze design features requiring a design standard decision document (DSDD), project alternatives, or to optimize geometric features due to right-of-way, funding, or other constraints, such as for complete streets projects. The HSM methodology is a tool intended to supplement the application of engineering judgement. Other features not reflected within the HSM methods, such as traffic control devices, etc., may be used as mitigation for certain nonstandard design features. These mitigating features will have beneficial impact and should be considered as part of the design for the project.

Caltrans acknowledges there are limitations inherent to the HSM which may limit its application. Absent another quantitative safety analysis methodology, the HSM represents the latest proactive safety performance analysis available.

Caltrans employees who are interested in additional HSM information and training can see Caltrans' internal Performance-Based Design website[4].

1.2 Collision Severity

Per Director's Policy 36 "Road Safety," Caltrans prioritizes eliminating fatal and serious injury collisions. Where the HSM can be applied, the resulting analysis allows practitioners to predict fatal and injury collisions due to proposed project features or design variations. This information can be utilized to support changes to project features or additional mitigations to address these collision severities.

The HSM Part C methodology and analysis tools provide a breakdown of collision severities which differ depending on the facility type. At a minimum, an HSM analysis will provide the following collision severities regardless of facility type:

1. Total collisions (T)
2. Fatal and Injury collisions combined (F&I)
3. Property Damage Only (PDO) collisions

These collision severities can provide valuable information; however, the general "injury" collision severity identified in category 2 described above combines several injury collision severities that can provide more valuable information if they are available separately. Ideally, any quantitative predictive safety analysis tool would provide a breakdown of collision severity types based on the "KABCO" injury scale which was developed by the National Safety Council[5] and is frequently adopted by law enforcement:

- K = fatal injury
- A = severe injury

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[3] https://dot.ca.gov/-/media/dot-media/programs/safety-programs/documents/policy/dp_36-a11y.pdf

[4] https://design.onramp.dot.ca.gov/performance-based-design

[5] National Safety Council. *Manual on Classification of Motor Vehicle Traffic Accidents, Fifth Edition* (ANSI D-16.1-1989). National Safety Council, Itasca, IL

- B = other visible injury
- C = complaint of pain
- O = property-damage only collisions

Using the KABCO scale will provide a more refined effect of each alternative or design feature on collision severity reduction. When collisions are not available in the KABCO scale, F&I and PDO collision reporting is the next preferred data because it will still indicate an alternative or a design feature's effects on collision severity. The least preferred collision reporting is total collisions because it uses a single average value for all collisions. When only total collisions are available, analyzing alternatives or design features cannot distinguish collision severity differences.

Table 1 below identifies the predicted collision severity breakdown provided by each facility type and its associated analysis tool.

Table 1 – Available Highway Safety Manual Tools & Predicted Collision Severity Output Results

Facility Type Tool	**Collision Severity Output**							
	T	F&I	F&I*	F (K)	A	B	C	O (PDO)
Rural Two-Lane Two-Way Roads Spreadsheet	X	X		X[1]	X[1]	X[1]	X[1]	X
Rural Multi-Lane Highways Spreadsheet	X	X	X					X
Urban & Suburban Arterials Spreadsheet	X	X						X
Freeways, Ramps and Ramp Terminal Intersections ISATe Spreadsheet	X	X		X	X	X	X	X
IHSDM (All facility types)	Mirrors the output for each facility as indicated above							

Legend:

T = Total Collisions
F = K = Fatal Collisions
A = Severe Injury Collisions
B = Other Visible Injury Collisions
C = Complaint of Pain Injury Collisions
O = PDO = Property Damage Only Collisions
F&I = All Fatal & Injury Collisions Combined
F&I* = Fatal (F) and Severe and Other Visible Injury Only Collisions (A+B) Combined
ISATe = Enhanced Interchange Safety Analysis Tool
IHSDM = Interactive Highway Safety Design Model
[1] = HSM Tables 10-3 and 10-5 provide a breakdown by percentage of total roadway collisions to the KABCO scale. The spreadsheet-based analysis tools do not provide these output values separately.

The HSM Part C analysis tools can provide a prediction for the expected life of the project improvements (i.e., 20 years of collisions) in terms of number of collisions, but the HSM does not by itself quantify a project's monetary safety benefits. Comparing the change in number of fatal, injury, and PDO collisions from a standard to nonstandard design to the additional cost needed to meet the standard is subjective since it is a comparison or evaluation of project elements in different units (dollars verses number of collisions). This comparison of different units can introduce bias based on an individual's perception of the value of the collisions. To reduce bias, a comparison based on a common and understandable unit of measure should be made, such as dollars.

1.3 Caltrans Tools

The Caltrans Headquarters Division of Design, Office of Project Support has developed several easy-to-use spreadsheet-based tools to assist in applying the HSM to projects on the State Highway System. The "Caltrans HSM Screening Tool" can be used to determine if the HSM can be used for a project's alternative analysis or nonstandard feature evaluation, based on scope, traffic volumes, and geometric and operational features. The results of this screening tool can also be used to help determine HSM analysis resource needs for future project phases.

Additionally, the "Caltrans Collision Cost Worksheet" has been developed to help practitioners navigate the conversion calculations from the numbers of F&I and PDO, or total collisions to dollars. This tool works best when collisions are available in the KABCO scale as this is the most preferred data to be used. Although some of the AASHTO HSM spreadsheet tools cannot provide a KABCO scale collision breakdown, Caltrans' Collision Cost Worksheet can still perform the conversion calculations when only total, F&I, and PDO collisions are available.

Currently, the "Caltrans HSM Screening Tool" is not available for use outside of the District HSM subject matter experts (SMEs) and the "Caltrans Collision Cost Worksheet" tool is not available for use outside of the Headquarters Design, Office of Project Support HSM SMEs. Contact the appropriate SME[6] for assistance with the Caltrans tools.

1.4 Project Costs and Benefits

For most transportation projects, the majority of investment costs are expended during the initial years for environmental mitigation, right-of-way acquisition, and construction. Whereas the transportation benefits from these initial investments generally accrue over many years after the project has been completed and opened to traffic. When assessing the benefits and costs of project alternatives, intersection type, or a proposed a nonstandard feature, it is necessary to take the initial costs and future benefits into account. A project's benefits may include a reduction in fatal, injury, and property damage only (PDO) collisions, reduction in travel time, reduction in greenhouse gas emissions, improved mobility, and local community satisfaction, among others.

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[6] https://design.onramp.dot.ca.gov/performance-based-design

1.4.1 Costs

Environmental clearances and mitigation, right-of-way acquisitions (permanent or temporary acquisitions, easements, utility relocations, etc.), future maintenance costs, and construction are a project's primary cost elements. Estimating those costs to evaluate projects and project alternatives is performed at various stages throughout the project development process. Additionally, a designer must consider the costs to make project features consistent with current design principles, i.e., "cost to make standard," typically per the Highway Design Manual[7] when preparing DSDDs.

1.4.2 Benefits

After a project is completed, the primary benefits realized are often a reduction in travel time or delay, or a reduction in collision frequency or severity. Monetary values can be assigned to these benefits to provide a comparison of initial costs to long-term benefits. The Division of Traffic Operations has historically estimated delay in the traffic analyses of project alternatives. Collision costs can be calculated by multiplying collisions by collision costs in Table 6.

The HSM provides the criteria to quantify a project's long-term safety effects which then enables a monetary safety performance value calculation. Quantified safety becomes another factor on which decisions are made. At a minimum, two costs should be calculated to evaluate the change in the number of collisions for an alternative analysis:

(1) the cost of collisions without the project (i.e., the "no-build" alternative) for the full design life of the project (typically a 20-year design period) and

(2) the cost of collisions with the project or alternative(s) using the same design life.

The "No-Build" alternative is the alternative where no project occurs, and the existing conditions remain. The difference in (1) and (2) is the safety benefit of the proposed project alternative(s). For DSDDs, benefits are calculated from the change in collision costs associated with the nonstandard feature and the collision costs associated with the same feature meeting standard.

Chapter 2: Application of the Highway Safety Manual

The HSM Part C "Predictive Methods" uses predictive models to estimate the collisions associated with changes in traffic and geometric characteristics of a roadway. Although a model's traffic and geometric characteristic inputs can vary for each facility type, there are consistent model inputs, such as Annual Average Daily Traffic (AADT), area type, intersection control type, and number of lanes. These and other characteristics are used to select the appropriate HSM Part C analysis tool and are entered into the selected tool to calculate the number of collisions per year.

AASHTO's Rural Two-Lane Roadway, Rural Multilane Roadway, and Urban/Suburban Arterials HSM analysis tools calculate collisions for a single year for specific geometric and operational conditions. To estimate collisions for the entire life of the project,

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[7] https://dot.ca.gov/programs/design/manual-highway-design-manual-hdm

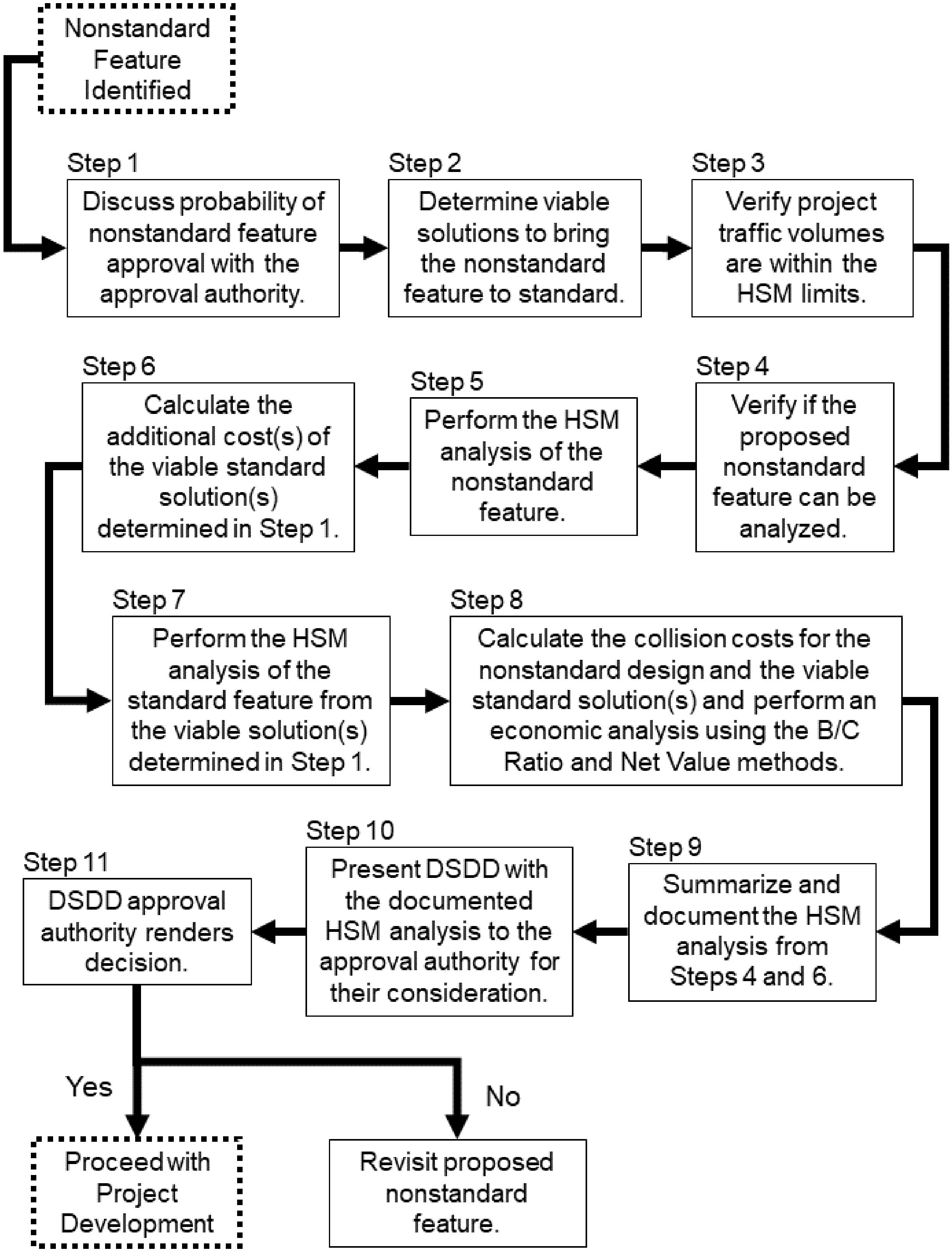
calculate the collisions for each year of the design life, which is typically a 20-year design period, and sum the individual year's calculated values. Therefore, extrapolation and repetitive actions may be needed when using the HSM Part C spreadsheet-based tools. Other AASHTO tools, such as the Enhanced Interchange Safety Analysis Tools (ISATe) used for a freeway analysis and the Interactive Highway Safety Design Model (IHSDM), will perform all 20 years of the design period calculations in one iteration.

2.1 Nonstandard Feature Evaluation Process

DSDDs are critical in maintaining design immunity and for being good stewards of Caltrans' resources. The DSDD is a design exception document allowed by the Federal Highway Administration in recognition that it is not always possible to meet minimum approved design standards in a project. Meeting all design standards for all projects regardless of cost or impacts is not practical in many cases. The costs to construct, purchase right-of-way, and minimize environmental impacts or the impacts to a community because of a design can far exceed the benefit of meeting a design standard. The intent of using the HSM to evaluate nonstandard features during the PA&ED and PS&E phases is to help engineers determine if the additional cost associated with bringing the feature to minimum standard is a worthwhile investment of transportation dollars, or if the same cost is better spent on another nonstandard feature that yields a higher benefit. A collision analysis for nonstandard geometrics includes all geometric changes needed to make the feature standard. For example, if a road would need to be realigned to achieve a standard shoulder, then all changes to the alignment also need to be modeled.

The economic evaluation of meeting a standard for a DSDD should be done using the Benefit to Cost (B/C) Ratio and Net Value methods described in Appendix C: Project-Level Economic Evaluation Methodologies. The flowchart shown in Figure 1 depicts the process to apply the HSM to evaluate nonstandard features.

Figure 1 – Flowchart for the Nonstandard Feature Evaluation Process using the Highway Safety Manual



2.1.1 Recommended Steps for Evaluating Nonstandard Features

1. Discuss probability of nonstandard feature approval with the approval authority[8]. Review the project's Project Initiation Document (PID), where applicable, to determine the approval probability for the identified nonstandard feature(s). Verify the probability is still current with the approval authority. Where a PID is not available, or additional proposed nonstandard features have been identified in PA&ED or PS&E, discuss the proposed nonstandard feature(s) with the appropriate approval authority to determine the probability of approval. If it's determined that the identified proposed nonstandard feature(s) is approvable, proceed with the next steps. If the identified proposed nonstandard feature(s) is not approvable, revisit the design.
2. Determine viable solutions to bring the nonstandard feature to standard. There could be several ways to meet the standard, and depending on how the solutions vary, it may be necessary to calculate predicted collisions for several viable standard solutions or just the most reasonable solution. Work with the District Design Liaison and the District HSM SMEs to determine what will need to be analyzed.
3. Verify project traffic volumes are within the HSM limits. For all the different facility or site types with nonstandard features, verify if the annual average daily traffic (AADT) for the project's design life is within the AADT ranges of the appropriate HSM Safety Performance Function (SPF). The AADT used in this step is the average of the 3 most recent continuous years of count volume data. For example, a freeway project involving work on the mainline and an interchange reconfiguration would need to verify the mainline AADT, each ramp AADT, the ramp terminal AADTs, and intersection crossroad AADTs are within ranges for those facility/site types.
4. Verify if the proposed nonstandard feature can be analyzed. For the facilities that meet the AADT in Step 2, verify if the proposed nonstandard feature(s) can be modeled with the HSM based on the facility/site type. If the Part C SPF contains an input variable or an associated CMF that matches the nonstandard feature, then it may be possible to model the feature.
5. Perform the HSM analysis of the nonstandard feature. Verify the proposed nonstandard features are segmented correctly per the appropriate HSM facility and stie type with the District HSM SMEs. Calculate the predicted collisions for the road segment(s) or intersection(s) with the nonstandard feature proposed by the project. This calculation should be for the life of the project, resulting in the total number of collisions. If AADT are only projected for opening year and for design year, a linear interpolation of the AADT may be acceptable for the years in-between. Before using a linear interpolation, consider if there are known events that will change the AADT between the opening and design years, such as a nearby project that will change traffic patterns, or a nearby development that

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[8] See the current District Design Delegation Agreements to determine the appropriate approval authority: https://design.onramp.dot.ca.gov/project-delivery-coordinators-district-design-liaisons

will open sometime after construction is complete. This information should be included in the traffic forecasting.

Conduct the HSM analysis for each year of the project’s design life since the model equations and adjustment CMF may not have a linear relationship to the AADT.

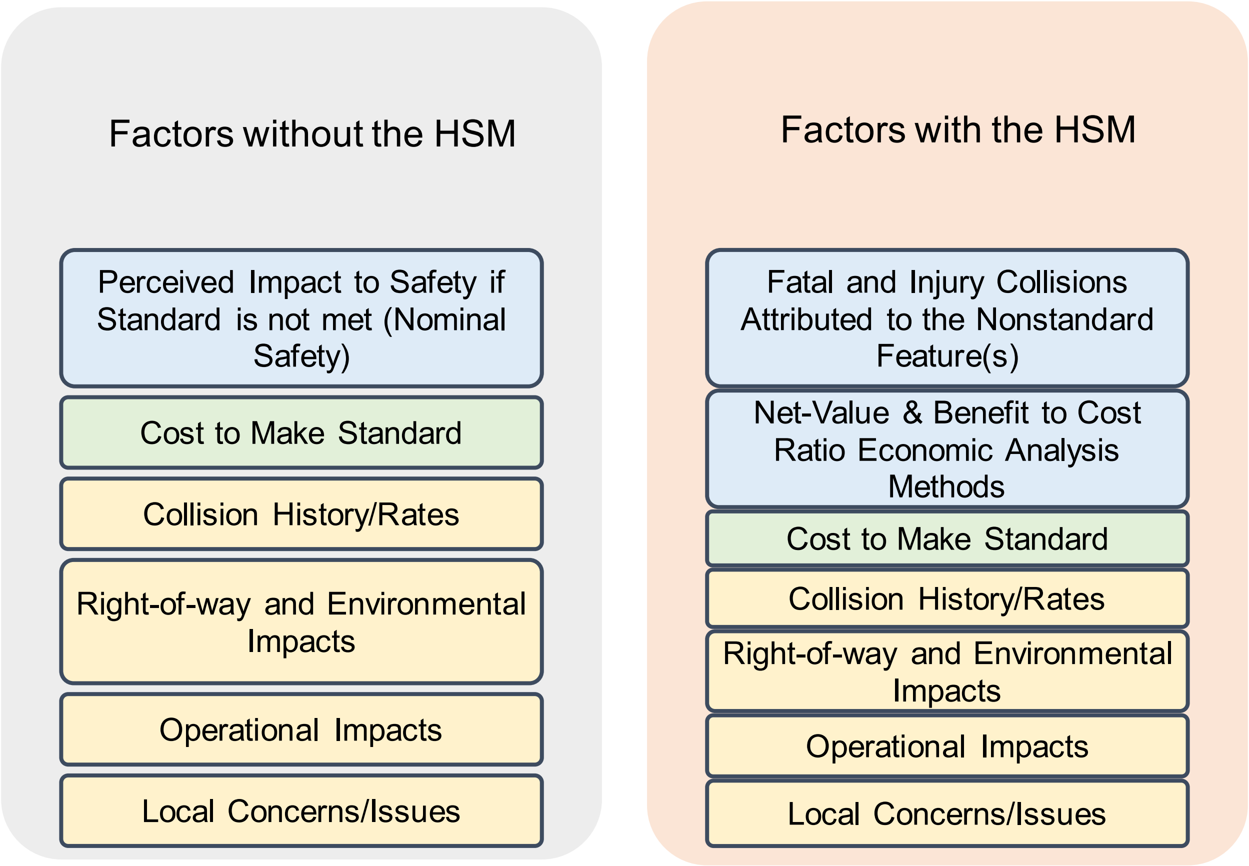
For a more complex analysis, such as a tradeoff analysis where multiple features are analyzed together to determine the best combination of widths for the space available, consider what combination of the various widths (i.e., some widths standard and some nonstandard or all nonstandard widths depending on the situation) that will result in the lowest number of fatal and severe injury collisions.

6. Calculate the additional cost(s) of the viable standard solution(s) determined in Step 1. This is the cost to make the design standard. At minimum, this includes the additional cost to construct, purchase right-of-way, and implement any additional environmental mitigation.
7. Perform the HSM analysis of the standard feature from the viable solution(s) determined in Step 1. Calculate the collisions using HSM Part C methods for each viable standard solution determined in Step 1 being carried forward. Revisit Step 4 if the viable solution(s) include significant changes that may result in changes to the modeled limits.
8. Calculate the collision costs for the nonstandard design and the viable standard solution(s) and perform an economic analysis using the B/C Ratio and Net Value Methods. The economic analysis should compare the nonstandard design to the viable standard solutions. Use the Caltrans Collision Cost Worksheet tool to calculate the collision costs for the proposed nonstandard design and the viable standard solution(s) determined in Step 1. This tool will also calculate the B/C Ratio and Net Value.

   The B/C Ratio and Net Value methods utilize quantitative factors like the change in predicted F&I collisions and represent substantive safety. This contrasts with qualitative factors such as simply whether a design standard was met, which is representative of nominal safety. All other factors to determine the acceptability of a nonstandard approval still need to be evaluated, see Figure 2.
9. Summarize and document the HSM analysis from Steps 4 and 6. The summary should include an interpretation of (1) the HSM analysis results, and (2) the economic analysis. The intent of this step is to include sufficient information that demonstrates engineering judgement was applied to support the recommended approval of the nonstandard design.
10. Present DSDD with the documented HSM analysis to the approval authority for their consideration. The DSDD approval authority will determine whether the B/C Ratio or Net Value shows that it’s a worthwhile use of funds when taking into consideration all the other project impacts. While the results of the HSM analysis may appear to demonstrate the benefits of using a nonstandard design, the approval authority retains DSDD approval discretion.

11. DSDD approval authority renders decision. If the approval authority approves the DSDD, proceed with project development. If the approval authority does not approve, solicit feedback to revisit proposed nonstandard feature.

Figure 2 – Factors Used to Evaluate Nonstandard Features



2.1.2 Documentation

The HSM analysis should not be attached or inserted into the DSDD. The DSDD should contain a summary of the results, like how the traffic analysis is a summary of the relevant information. Document the relevant factors of the methodology used and assumptions of the HSM analysis in the project history file with concurrence from the District's Design and Traffic Operations or Traffic Safety HSM SME, which will help defend project decisions should litigation arise. The approval authority may request, with supporting reasons, additional information be documented.

There are many facility types, facilities with high traffic volumes, and design features that cannot be analyzed using the HSM Part C. When the HSM Part C methods cannot be used, document and explain the reasons for not including the HSM analysis in the DSDD. This could be a simple sentence in PDPM Appendix BB's Section 4 "Collision Analysis" or as part of an introduction prior to the discussion of nonstandard features in PDPM Appendix BB Section 2 "Features Requiring Design Decision Documentation."

For each nonstandard feature that can be analyzed with the HSM, calculate the B/C Ratio and Net Value, and include discussion in PDPM Appendix BB's Section 2, "Reason for not Using Design Standard." The discussion should include a summary of the HSM analysis results along with a justification for not meeting the minimum standard and other deciding factors that explain why it's the most optimal outcome for the travelling public at this time. The following is an example of wording that may be used for simple projects or project features:

> *"Upon evaluating the difference in predicted collisions between meeting the standard width of X and the proposed nonstandard width of Y, the calculated collision benefit of meeting standard over the design life (B) compared to the cost required to meet that standard (C) results in a Benefit to Cost (B/C) Ratio analysis equal to "A." This indicates that for every dollar spent to meet the standard for this project, there would be "A" dollars of benefit that may be realized over the design life. The Net Value analysis (B – C) indicates that "D" dollars of calculated collision benefit will be realized over the project's cost spent to meet the required standard."*

For a tradeoff analysis, discuss why, for example, a median width of X, inside shoulder width of Y_1, lane widths of Z and outside shoulder of Y_2 is the best combination of widths in terms of safety performance. The dimensions "X," "Y_1," "Z," and "Y_2" may be any combination of standard and nonstandard features. The results of the trade-off analysis would inform the DSDD's HSM analysis and conclusion.

If only a portion of the project or some of the features can be analyzed, document the features that can and cannot be analyzed, explaining why an HSM analysis was only performed for some features or not all. Features that cannot be analyzed can be documented in a note in a table of nonstandard features, or in an entirely new section if additional discussion is needed. Features that can be analyzed should follow the documentation guidance above. An example of a project that contains features that can and cannot be analyzed is a freeway project modifying an interchange where the freeway mainline traffic volumes exceed the HSM limits, but some ramp traffic volumes are within the HSM limits and nonstandard features are proposed and can be analyzed.

2.1.3 Design Standard Decision Document Highway Safety Manual Disclaimer

Add the following disclaimer after the Highway Safety Manual results, analysis, and summary:

> *The HSM results and analysis are not intended to be the only information that decisions are based upon, nor are they intended to be a substitute for the exercise of sound engineering judgement."*

2.1.4 Design Standard Decision Document Sample

> *A predictive safety analysis was performed using the 2010 Highway Safety Manual (HSM) to evaluate the safety performance of the*

> *proposed nonstandard shoulder width versus a standard shoulder width over the 20-year design life and the results are shown in Table 1 below. Following the HSM analysis, an economic evaluation was performed to evaluate the cost-effectiveness of the additional costs required to meet the standard shoulder width versus the safety performance over the 20-year design life. The economic evaluation of an additional $1,318,000 cost to meet the standard shoulder width with an associated $51,975 of safety benefits over the 20-year design life equates to a Benefit to Cost Ratio of 0.04 and a Net Value of $-1,266,025. The benefit in collision reduction because of meeting the standard shoulder width is not economically justifiable compared to the costs required to meet the standard shoulder width.*
>
> *Table 1 – Summary of HSM Predictive Analysis over the Design Life*
>
> | *Design Feature* | *Fatal & Injury (F&I) Collisions* | *Property Damage Only (PDO) Collisions* |
> |---|---|---|
> | *Standard Shoulder Width* | *0.6* | *1.2* |
> | *Nonstandard Shoulder Width* | *0.7* | *1.4* |
>
> *The HSM results and analysis are not intended to be the only information that decisions are based upon, nor are they intended to be a substitute for the exercise of sound engineering judgement.*

Note that use of a table shown in the sample above is optional and should not be used to replace the HSM summary. Some considerations for use or disuse of a table may include but are not limited to simplifying the HSM summary, communication supplementation, preference of the approval authority, among others.

2.2 Project Alternative Analysis Process

[Reserved]

2.3 Trade-off Analysis Process

[Reserved]

2.4 Qualitative Analysis Process

[Reserved]

Appendix A: Performance-based Decision-making using the Highway Safety Manual memorandum on April 4, 2022

State of California
DEPARTMENT OF TRANSPORTATION

California State Transportation Agency

Memorandum

To: DEPUTY DISTRICT DIRECTORS, DESIGN
DEPUTY DISTRICT DIRECTORS, TRAFFIC OPERATIONS

Date: April 4, 2022

From: JANICE BENTON
Chief
Division of Design

RACHEL CARPENTER Monica Wooster for
Monica Wooster for (Apr 4, 2022 12:23 PDT)
Chief Safety Officer

Subject: PERFORMANCE-BASED DECISION-MAKING USING THE HIGHWAY SAFETY MANUAL

This Memorandum supersedes the August 12, 2019 *Project Guidance for Performance-Based Decision-Making Using Highway Safety Manual* memorandum. The purpose of this Design Memoranda is to convey the expectations for implementing performance-based decision-making processes using the American Association of State Highways and Transportation Officials (AASHTO) Highway Safety Manual (HSM) on state highway projects.

The HSM is a nationally recognized tool that facilitates decisions on highway projects by providing a predictive quantitative performance-based assessment based on how these decisions affect collisions. The goal of this updated guidance document is to support the integration of predicted roadway safety performance considerations throughout the highway transportation planning and project development process.

This guidance is intended to supplement the information on which project decisions are currently based and is not intended to act as the only factor driving project decisions nor does it include every situation. Project decisions are to be made using engineering judgement and experience based on specific project conditions and requirements and strive to balance pertinent values (e.g., modal priorities, community goals and objectives, environmental resources, social impact, economic impacts, and fiscal resources, etc.). The key to a successful project includes weighing and carefully considering each of these tradeoffs with the collision potential of each proposed alternative, geometric, or operation feature, and balancing the overall impacts to the State through discussions by the project development team.

The HSM shall apply to projects or analyses that meet the minimum criteria specified below and in accordance with *Attachment 1 - Performance-Based*

"Provide a safe and reliable transportation network that serves all people and respects the environment"

Decision-Making Guidelines using the Highway Safety Manual document (dated April 4, 2022):

- Effective immediately, projects on rural two-lane highways, rural multi-lane highways, and urban/suburban arterials that have not yet completed PA&ED (WBS M200). For these facility types, this follows the June 30, 2020 implementation date as outlined in the previous memo.
- Projects on freeways, ramps, and ramp terminals with a PA&ED (WBS M200) date after September 1, 2022.

If you have any questions or require assistance, please contact the HQ HSM support team at <HSM.Support@dot.ca.gov>. The Office of Project Support from Headquarters Division of Design, and Office of Strategic Safety and Implementation from Headquarters Division of Safety Programs monitor this email address and will provide assistance.

Attachment
1. Attachment 1 - Performance-Based Decision-Making Guidelines using the Highway Safety Manual

c: Michael Keever, Chief Deputy Director
Cory Binns, Deputy Director, Maintenance and Operations
Donna Berry, Acting Deputy Director, Project Delivery
Jasvinderjit Bhullar, Chief, Division of Traffic Operations
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Project Delivery Coordinators, Divisions of Design and Project Management

"Provide a safe and reliable transportation network that serves all people and respects the environment"

April 4, 2022

Attachment 1 – Performance-Based Decision-Making Guidelines using the Highway Safety Manual

The purpose of a Highway Safety Manual (HSM) analysis is to provide a quantitative performance-based safety analysis that facilitates the Department's safety-first goals and objectives in the decision-making process throughout project development which includes eliminating fatal and serious injury collisions. The HSM can facilitate design and operational decisions for projects on the State Highway System (SHS) by providing a quantitative safety assessment of how changes to those features affect predicted collisions. Prior to the HSM, only a subjective assessment of changes to design and operational features was possible using engineering judgement and experience. In effect, the HSM can provide a stronger focus on the potential safety impacts of the decisions that are made in project development.

Overview

The HSM is organized into four parts:

- Part A – Introduction, Human Factors and Fundamental knowledge.
- Part B – Roadway Safety Management Process.
- Part C – Predictive Methods for Rural Two-lane Highways, Rural Multilane Highways, Urban and Suburban Arterials, and Freeways and Ramps.
- Part D – Crash Modification Factors.

Roles and Responsibilities:

Headquarters (HQ) Division of Design (DOD)

- Designate and train HQ HSM Subject Matter Experts (SMEs).
- Provide technical assistance in HSM applications to District Design staff.
- Coordinate and collaborate with the HQ Safety Programs, and District Design HSM SMEs to:
  - Develop technical expertise in HSM analysis methods;
  - Implement the use of the HSM;
  - Support District Design's use of the HSM for project delivery; and
  - Develop and maintain guidance and tools to facilitate the use of the HSM throughout project development.

HQ Division of Safety Programs

- Designate and train HQ HSM SMEs.
- Provide technical assistance in HSM applications to District Traffic Safety, and Traffic Operations staff.

- Coordinate and collaborate with HQ Design, and District Traffic Operations and Traffic Safety SMEs to:
    - Develop technical expertise in HSM analysis methods;
    - Implement the use of the HSM; and
    - Support the District's Safety Program's use of the HSM.
- Develop and maintain California collision cost information such that it can be applied directly to HSM tools outputs and California-specific safety performance functions and crash modification factors. Communicate updates to collision cost information to HQ DOD.
- Coordinate with HQ DOD to update guidance and tools when California specific calibration factors or safety performance functions and crash modification factors are developed.

Project Delivery Team (PDT)

- Determine the need and usefulness of a HSM analysis for making performance-based decisions throughout project delivery.
- Consult with the District Design and Traffic Safety Program's HSM SMEs, as needed.
- Weigh and balance the overall impacts to the State through consideration of tradeoffs associated with the performance-based safety analysis.

District Division of Design

- Design management is to designate District HSM SMEs and see that they are trained and resourced to:
    - Coordinate and collaborate with the HQ DOD, HQ Division of Safety Programs, and District Traffic Operations and Traffic Safety HSM SME(s);
    - Train District staff; and
    - Provide technical assistance to support HSM application.
- Determine when an HSM analysis is required, if and how it can be applied to a project, and review the HSM analysis.
- Provide needed geometric data required for District (Design, Traffic Operations, or Traffic Safety) to perform the HSM modeling.
- Review an HSM analysis for projects funded by others and performed by other Divisions.
- Support PDTs as needed.
- Request/include necessary resources to perform or review a pre-modeling analysis, HSM modeling, post-modeling analysis and documentation.

District Division of Traffic Operations and Division of Safety Programs/Traffic Safety

- Traffic Management is to designate District HSM SME's and see that they are trained and resourced to:
  - Coordinate and collaborate with the HQ DOD, HQ Division of Safety Programs, and District Design HSM SME(s);
  - Train District staff; and
  - Provide technical assistance for HSM applications to support Capital Outlay Support (COS) and safety project delivery, encroachment permit projects, and Local Development-Intergovernmental Review (LD-IGR) projects.
- Provide needed traffic related data (such as, but not limited to, Traffic Accident Surveillance and Analysis System (TASAS) data, Traffic Collison Reports, AADT, signal phasing, traffic delay, etc.) needed for District (Design, Traffic, or Safety) to perform HSM modeling and analysis on all projects, including non-safety projects.
- Support PDTs, as needed.
- Request/include necessary resources to perform or review a pre-modeling analysis, HSM modeling, post-modeling analysis, and documentation.
- Review an HSM analysis for Local Development - Intergovernmental Review (LD-IGR) Safety Reviews if provided as part of the LD-IGR Traffic Investigation Report.
- Determine when an HSM analysis is required, if and how it can be applied to a project, and review the HSM analysis.
- Review an HSM analysis for projects funded by others and performed by other Divisions.

Engineer in Responsible Charge of Project Development in Current Phase

- Conduct an HSM analysis in consultation with the District Design, Traffic Operations, and Traffic Safety HSM SMEs.
- Document outcomes of the HSM analysis, or why an HSM analysis was not applicable, in the appropriate project document (e.g., project approval document, Design Standard Decision Document (DSDD), HSM analysis methodology, and/or project history file (see Limitations below)).

Project Application:

The HSM Part C methodology can be used as a tool to predict collisions, however, as with any tool, limitations may apply which could preclude its use. For the HSM, these limitations may include traffic volume limits or number of lane limits, a facility type that is not yet included, or certain geometric or operational features that cannot be explicitly analyzed. The HSM is limited on the facility types that can be analyzed when comparing the HSM methodology to the Highway Safety Improvement Program (HSIP) methodology; however, the HSM can analyze more geometric features. Therefore, the HSIP methodology is currently used to qualify safety projects and the HSM methodology may be used in the future to supplement this analysis. The HSIP methodology does not replace an HSM analysis for projects in Project Approval & Environmental Document (PA&ED) or Plans, Specifications, and Estimates (PS&E) phases.

Where the HSM Part C predictive methods can be applied, the HSM shall be used for all projects on the SHS regardless of project sponsor or funding source, if it is proposing any of the following:

- Nonstandard design feature(s).
- A geometric or operational feature that varies from the existing condition or from other project alternatives.
- New or modification to an interchange as part of the alternative selection process and Interstate New Access Report or Modified Access Report.

Analysis:

The HSM can predict collision performance using Safety Performance Functions (SPFs). The SPFs presented in the HSM are not California-specific, although California data was also used in some instances, and have been derived from detailed analysis of Traffic Collision Reports across the country using before/after analysis of select safety countermeasures and their impact on reducing fatal, injury, serious injury and property damage only collision types. HSM-developed SPFs should be used until California-specific information is available for use for the project types described in this document.

HSM Part C method analysis tools should be used for the following types of evaluations:

- Comparison between project alternatives for project alternative selection: difference in number of fatal and injury collisions, Cost to the State, and Benefit/Cost (B/C) ratio.
- Comparison between meeting standard and a proposed nonstandard geometric feature for a DSDD: difference in number of fatal and injury collisions, B/C ratio, net value, or Cost to the State.
- Trade-off analysis to find the most effective combination of geometric elements that fit within project constraints.

HSM Part D methodology applies to Crash Modification Factors (CMFs) outside of Part C (e.g. Part D of the HSM), and includes FHWA's CMF Clearinghouse (http://www.cmfclearinghouse.org) among other resources. The CMF

Clearinghouse is an extensive, searchable, and frequently updated database of published CMFs based on completed transportation-safety related research. A CMF from the CMF Clearinghouse should be used only when there is a clear understanding of its origins and limitations.

For application of a Part D CMF to projects covered in this Attachment 1, all the following criteria must be met:

- Used to overcome the facility types limitations included in the HSM (e.g., added ability to model a two-way left-turn lane on a rural 4-lane facility, or to model a single-lane roundabout alternative, etc.)
- Must come from the CMF Clearinghouse or a Caltrans-specific preapproved CMF list developed with the HSM methodology.
- For a quantitative analysis, a Part D CMF must be applied to the output of a Part C method analysis.
- The District Design and Traffic Safety SME's both concur on its intended application.
- Used singularly – only apply one Part D CMF to a roadway segment or intersection at a time.
- The standard error of the CMF is applied appropriately, to provide a numerical range of potential effects on collisions.
- Use of a Part D CMF, application calculations, and meeting the above criteria are documented in the appropriate document (e.g., DSDD, HSM analysis methodology, project history file, etc.).

Limitations:

The HSM uses predictive methods to incorporate geometric and operational configurations using traffic volumes and other factors as a basis for analysis. Utilizing predictive methods outside the boundaries for which the tool was developed may bring the validity of the results obtained into question.

Therefore, understanding the limitations of the methods presented in the HSM and documenting project decisions are critical to a successful analysis.

When the HSM predictive methods cannot be applied to design alternatives, nonstandard features, or only a portion of the project can be analyzed, it should be documented in the appropriate report such as the project approval document and/or the DSDD and the project history file.

Appendix B: Example Projects

B.1 Example Project 1

For a hypothetical example project, Example Project 1 in an urban setting, compare Alternative A to Alternative B based on the initial project cost information provided in Table 2.

Table 2 – Example Project 1 Initial Project Cost Comparison

	Alternative A	**Alternative B**
Project Cost	$2,850,000	$3,236,000

If the decision for which alternative to move forward were based on project cost alone, Alternative A would be chosen simply because its project costs are lower. In some cases, an alternative's safety performance may affect the decision to move forward with a more costly project alternative. Knowing the safety performance for Example Project 1 Alternatives A and B, presented below in Table 3, may change which alternative is preferred.

Table 3 – Example Project 1 Total Predicted Safety Performance Information Comparison (20-year)

	Alternative A	**Alternative B**
Project Cost	$2,850,000	$3,236,000
Total Collisions	30.4	31.9

Since Alternative A has the lowest project cost and the fewest total annual collisions over the design life, it still appears to be the most beneficial alternative with all other project factors being equal. There may be more information that could aid in the decision-making process, such as the breakdown of collision severities which are depicted in Table 4 below.

Table 4 – Example Project 1 Predicted Collision Severity Comparison (20-year)

	Alternative A	**Alternative B**
Project Cost	$2,850,000	$3,236,000
Collision Severity	Collisions	
K	1.4	1.2
A	2.0	1.6
B	2.2	2.3
C	10.0	10.7
O	14.8	16.1
Total Collisions	30.4	31.9

Although Alternative A is shown to have the lowest project cost and the fewest total annual collisions, Alternative B will result in the fewest fatal (K) and severe injury (A) collisions. Knowing the number and severity of collisions for each alternative can help the decision-makers analyze which alternative has the best safety performance that meets the purpose-and-need, to weigh along with other project factors.

It is beneficial to know how proposed alternatives may change the number of collisions, collision types, and severities when comparing to the existing condition and to other alternatives. Ideally, proposed project alternatives would reduce collisions when compared to the existing condition, but this is not always the case. For example, a new interchange adds conflict points where the ramps connect to the mainline facility, and where the ramps connect to the local road at the ramp terminal intersections. These added conflict points add collision potential. In these cases, analyzing which alternative results in the smallest change in collisions when compared to the “No-Build” collisions may help determine which alternative is selected. The change in collisions for Example Project 1 from the “No-Build” alternative to Alternatives A and B are shown in Table 5 below. **Although the alternatives result in a reduction of collisions, it is not indicated by negative numbers. Any relative change in collisions, whether positive or negative, should be noted in the appropriate documentation.**

Table 5 – Example Project 1 Change in Collision Comparison to No-Build Alternative (20-year)

	No-Build	**Alternative A**		**Alternative B**	
Project Cost (C)	$0	$2,850,000		$3,236,000	
Collision Severity	Collisions	Collisions	Change from No-Build (Collisions)	Collisions	Change from No-Build (Collisions)
K	1.7	1.4	0.3	1.2	0.5
A	2.4	2.0	0.4	1.6	0.8
B	3.0	2.2	0.8	2.3	0.7
C	13.8	10.0	3.8	10.7	3.1
O	23.2	14.8	8.4	16.1	7.1
Total Collisions	44.1	30.4		31.9	
Total Change (Collisions)			13.7		12.2

Alternative B is shown to produce the greatest reduction in the fatal and severe injury collision types (i.e., the greatest change in collisions when compared to the “No-Build” collisions). A collision severity breakdown provides a more thorough look at potential safety impacts, in addition to looking at total collisions reduced. However, as noted previously, comparing project costs to number of collisions is open to subjectivity based on one’s perspective which can introduce bias and lead to difficulty in determining the best use of dollars spent.

Converting the collisions to a monetary amount allows a comparison of collisions in dollars to alternative cost in dollars; therefore, this dollars-to-dollars comparison reduces bias in the evaluation.

Collision costs result in tangible and intangible consequences. The tangible consequences, or economic costs, can be directly measured in monetary terms (e.g., medical bills, lost wages). The intangible consequences, such as the physical pain and emotional suffering of people injured and their families, include the other impacts of collisions. The intangible consequences can be monetized as quality-adjusted life years.

Given the tangible and intangible cost associated with collision severities, simply estimating the total number of collisions associated with a project improvement is not sufficient to understand the consequences of those collisions. For example, when converting a signalized intersection to a multi-lane entry roundabout, the total collisions may not change or may even increase. Still, Caltrans' Intersection Safety and Operational Assessment Process (ISOAP) requires projects to consider a roundabout alternative because research has shown a 90% decrease in fatal collisions, and a 70% decrease in injury collisions[9]. A multi-lane roundabout's increase in collisions can usually be attributed to PDO collisions, which typically do not require emergency services or medical treatment and do not result in a reduction in quality of life.

Design and safety practitioners use collision costs to determine if safety improvement projects are economically justified and to quantify economic impacts of collisions. Collision cost valuations are based on a statistical analysis of estimated future tangible and intangible costs and are not meant to be used as evidence in litigation. A comprehensive cost estimate associated with these future tangible and intangible costs includes the monetary losses associated with medical care, emergency services, property damage, lost productivity, and the intangible cost related to the reduction in the quality of life. The dollar valuations differ from monetary awards that juries would make in a lawsuit dealing with a real injury or loss of life and are based on varied factors, which are governed by California law.

Caltrans has developed comprehensive hypothetical cost estimates for the various collision severities and location types. Table 6 below shows example numbers like Caltrans' collision costs for the various crash severities by area type (see note below table).

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[9] Persaud, B. N., Retting, R. A., Garder, P. E., & Lord, D. (2001). Safety Effect of Roundabout Conversions in the United States: Empirical Bayes Observational Before-After Study. Transportation Research Record, 1751(1), 1–8. https://doi.org/10.3141/1751-01

Table 6 – Example Collision Costs

Collision Severity	Example Highway Collision Costs ($/Collision)			
	Urban	Suburban	Rural	Average
Fatal	$11,300,000	$11,200,000	$11,800,000	$11,400,000
Injury	$165,000	$167,000	$170,000	$167,000
PDO	$15,000	$16,000	$12,000	$14,000
All Types	$200,000	$115,000	$250,000	$180,000

Note: The information in Table 6 is specifically for the statistical assessment of predictive project cost analysis examples in this document only; these costs are not to be considered as actual or useable for analysis and should not be used in civil litigation.

This information is subject to the provisions of 23 U.S.C. § 407, which provides reports, surveys, schedules, lists, or data compiled or collected for the purpose of identifying, evaluating, or planning the safety enhancement of potential accident sites, hazardous roadway conditions, or for the purpose of developing any highway safety construction improvement project which may be implemented shall not be the subject to discovery or admitted into evidence in a Federal or State court proceeding or considered for other purposes in any action for damages arising from any occurrence at a location mentioned or addressed. (23 U.S.C. § 407)

Reexamining Example Project 1 by calculating costs of collisions or changes in collisions with the information available in Table 6, we can now determine the monetary value of the collisions, or the monetary value for the change in collisions as shown in Table 7 below.

Table 7 – Example Project 1 No-Build Comparison with Collision Costs (20-year)

	No-Build	**Alternative A**				**Alternative B**			
Project Cost	$0	$2,850,000				$3,236,000			
Collision Severity	Collisions	Collisions	Collision Cost ($1,000s)	Change from No-Build (Collisions)	Change from No-Build (Collision Cost, $1,000s)	Collisions	Collision Cost ($1,000s)	Change from No-Build (Collisions)	Change from No-Build (Collision Cost, $1,000s)
K	1.7	1.4	$16,520	0.3	$3,540	1.2	$14,160	0.5	$5,900
A	2.4	2.0	$332.2	0.4	$66.4	1.6	$265.8	0.8	$132.9
B	3.0	2.2	$365.4	0.8	$132.9	2.3	$382	0.7	$116.3
C	13.8	10.0	$1,661	3.8	$631.2	10.7	$1,777	3.1	$514.9
O	23.2	14.8	$239.8	8.4	$135.2	16.1	$260.8	7.1	$114.2
Total Collisions	44.1	30.4				31.9			
Total Change (Collisions)				13.7					12.2
Total Change ($)					$4,506				$6,778

Alternative A, with a lower project cost but a smaller benefit in reduced fatal and serious injury collisions, and Alternative B, with a higher project cost but a higher benefit in reduced fatal and serious injury collisions, provides the design engineer with data in the same units, dollars, to aid in the selection of a project alternative along with other project factors.

For Example Project 1, one alternative reduces more dollars' worth of collisions, but the other alternative's project costs are lower. Note, that the alternative with the higher projects cost, Alternative B, is only $386,000 more, yet the predictive collision analysis estimates it to yield $2,272,500 of additional collision reduction benefits. Only providing cost and benefits in dollars is not sufficient to understand which alternative is a better value or is the most efficient use of dollars spent.

See Appendix C: Project-Level Economic Evaluation Methodologies for more information on the Net Value, Cost to the State, and Benefit to Cost (B/C) Ratio economic analysis methodologies applied in the following sections of this guidance.

Table 6 can be used to calculate collisions costs by multiplying collisions or change in collisions by the appropriate cost based on project context and severity. Applying the Net Value analysis method to Example Project 1, as shown in Table 8 below, yields a higher Net Value for Alternative B. Comparing Net Values can be easier than looking at the number of collisions reduced and the project cost to determine the alternative with the greatest net value.

Table 8 – Example Project 1 Net Value Analysis

	No-Build	**Alternative A**				**Alternative B**			
Project Cost (C)	$0	$2,850,000				$3,236,000			
Collision Severity	Collisions	Collisions	Collision Cost ($1,000s)	Change from No-Build (Collisions)	Change from No-Build (Collision Cost, $1,000s)	Collisions	Collision Cost ($1,000s)	Change from No-Build (Collisions)	Change from No-Build (Collision Cost, $1,000s)
K	1.7	1.4	$16,520	0.3	$3,540	1.2	$14,160	0.5	$5,900
A	2.4	2.0	$332.2	0.4	$66.4	1.6	$265.8	0.8	$132.9
B	3.0	2.2	$365.4	0.8	$132.9	2.3	$382	0.7	$116.3
C	13.8	10.0	$1,661	3.8	$631.2	10.7	$1,777	3.1	$514.9
O	23.2	14.8	$239.8	8.4	$135.2	16.1	$260.8	7.1	$114.2
Total Collisions	44.1	30.4				31.9			
Total Change (Collisions)				13.7					12.2
Total Change ($) (B)					$4,506				$6,778
Net Value (B – C)					$1,656				$3,542

When the Net Value method is used for DSDD justification, the benefit is the collision reduction of meeting the minimum standard versus the proposed nonstandard feature. This is typically done by comparing the number of collisions for the nonstandard feature versus the number of collisions for the standard feature. However, sometimes there may be other changes needed to meet standard. For example, it may not be possible to widen to one side to meet the minimum shoulder width without realigning the road to avoid an obstruction. For this and other similar cases, all changes needed to meet standard would need to be analyzed and evaluated for the accumulated effect on collisions, as would all the costs to meet standard. This can result in additional design details in the cost estimate to make standard, since a preliminary footprint of the realignment would be required to predict the number of collisions for the minimum standard scenario.

Applying the Cost to the State analysis method to Example Project 1, as shown in Table 9 below, yields a higher cost to the State for Alternative A. Performing a Cost to the State analysis is simple and the outcome leads to a similar comparison to comparing project alternatives costs. The lowest overall cost to the State would indicate the project that has the lowest economic impact to the State as a whole, not just to Caltrans.

Table 9 – Example Project 1 Cost to the State Analysis

	No-Build	**Alternative A**				**Alternative B**			
Project Cost (C)	$0	$2,850,000				$3,236,000			
Collision Severity	Collisions	Collisions	Collision Cost ($1,000s)	Change from No-Build (Collisions)	Change from No-Build (Collision Cost, $1,000s)	Collisions	Collision Cost ($1,000s)	Change from No-Build (Collisions)	Change from No-Build (Collision Cost, $1,000s)
K	1.7	1.4	$16,520	0.3	$3,540	1.2	$14,160	0.5	$5,900
A	2.4	2.0	$332.2	0.4	$66.4	1.6	$265.8	0.8	$132.9
B	3.0	2.2	$365.4	0.8	$132.9	2.3	$382	0.7	$116.3
C	13.8	10.0	$1,661	3.8	$631.2	10.7	$1,777	3.1	$514.9
O	23.2	14.8	$239.8	8.4	$135.2	16.1	$260.8	7.1	$114.2
Total Collisions	44.1	30.4				31.9			
Total Change (Collisions)				13.7					12.2
Total Change ($) (B)					$4,506				$6,778
Net Value (B – C)					$1,656				$3,542
Total Collision Cost (TCC)			$19,118				$16,846		
Cost to the State (TCC + C)			$21,968				$20,082		

Applying the B/C Ratio analysis method to Example Project 1, as shown in Table 10 below, yields a higher B/C Ratio for Alternative B. Another way to view the B/C Ratio is by determining how many dollars of benefit per dollar spent. In this example, Alternative B has $2.1 of benefit for every dollar spent, which is $0.5 more benefit per dollar spent compared to Alternative A.

Table 10 – Example Project 1 Benefit to Cost Ratio Analysis

	No-Build	**Alternative A**				**Alternative B**			
Project Cost (C)	$0	$2,850,000				$3,236,000			
Collision Severity	Collisions	Collisions	Collision Cost ($1,000s)	Change from No-Build (Collisions)	Change from No-Build (Collision Cost, $1,000s)	Collisions	Collision Cost ($1,000s)	Change from No-Build (Collisions)	Change from No-Build (Collision Cost, $1,000s)
K	1.7	1.4	$16,520	0.3	$3,540	1.2	$14,160	0.5	$5,900
A	2.4	2.0	$332.2	0.4	$66.4	1.6	$265.8	0.8	$132.9
B	3.0	2.2	$365.4	0.8	$132.9	2.3	$382	0.7	$116.3
C	13.8	10.0	$1,661	3.8	$631.2	10.7	$1,777	3.1	$514.9
O	23.2	14.8	$239.8	8.4	$135.2	16.1	$260.8	7.1	$114.2
Total Collisions	44.1	30.4				31.9			
Total Change (Collisions)				13.7					12.2
Total Change ($) (B)					$4,506				$6,778
Net Value (B – C)					$1,656				$3,542
Total Collision Cost (TCC)			$19,118				$16,846		
Cost to the State (TCC + C)			$21,968				$20,082		
Benefit to Cost Ratio (B/C)					1.6				2.1

Appendix C: Project-Level Economic Evaluation Methodologies

Once a project's costs and benefits have both been expressed in dollars, there are several methods that can be used to evaluate and rank projects, project alternatives, or nonstandard features in the Project Approval and Environmental Document (PA&ED) and Plans, Specifications, and Estimate (PS&E) phases. These methods, in no order, are Project Costs, Net Value, Cost to the State, and Benefit to Cost Ratio.

C.1 Project Costs

This method highlights the project or alternative with the lowest cost to clear right-of-way, mitigate environmental impacts, and to construct. This has been the traditional method for decades used by Caltrans and local agencies and is one factor that's used in selecting the preferred project alternative.

Pros

- It is the way Caltrans and local agencies have often done business.
- It will not require a new process or work for project development.
- It minimizes the dollars spent on the project so that money can be spent on other roadway needs.

Cons

- It has a severe cost bias. There is no quantitative analysis comparing cost and benefits.
- It only provides subjective consideration on magnitude of benefits.

C.2 Net Value

This method is simply the algebraic difference between all monetized benefits (B) of the project and all the costs (C) over the life of the project (design period). The Net Value method is calculated as follows:

$$Net\ Value = B - C$$

This method can determine which alternative or nonstandard feature is the most cost-effective (i.e., which alternative has the more dollars of benefit over the cost to deliver the project). It may also be an effective method to evaluate if a project is economically justified. If an alternative or nonstandard feature's benefits are less than its initial cost ($B - C < 0$), the approval authority may conclude that the alternative or nonstandard feature is not a worthwhile investment because the project's long-term benefits do not outweigh its initial costs. But the alternative also must be weighed with the purpose-and-need of the project and all the other non-monetary factors that must be considered. An alternative with a net value greater than zero indicates that the project should deliver more monetized benefit than the estimated costs.

The Net Value method for a DSDD is calculated by subtracting the cost to meet the standard from the benefit of collision reductions over the project's design life. The Net Value method is calculated as follows:

$$\text{Net Value} = (\text{Collision Cost}_{\text{Nonstandard feature}} - \text{Collision Cost}_{\text{Standard feature}}) - (\text{Cost to meet the Standard})$$

There is no minimum Net Value that guarantees support for the additional investment is a good value. The DSDD approval authority determines an appropriate Net Value threshold for the project.

Pros

- It compares dollars of alternative costs to dollars of alternative benefits.
- It compares dollars required to meet a standard design to dollars of collision cost change for the nonstandard design.
- It favors the project alternative with a greater monetary net value.
- It highlights the alternative that has the greater effect on safety and delay benefits.

Cons

- It requires the calculation of the dollar value of benefits of collision reduction; Caltrans has not typically been evaluating projects in this manner.
- A weakness of this method is that the overall magnitude of costs/benefits is lost. For example, two alternatives could have the same net value of say $2,000,000 ($2 million more benefit than the cost of the alternative), but one alternative cost $1,000,000 and the other alternative cost $10,000,000. Both alternatives have the same net value, but one uses the public's financial contribution much more efficiently. Theoretically, ten projects like the $1,000,000 project could be constructed returning ten times the benefits of the more expensive project.
- It only works when a benefit can be calculated.
- It may favor higher cost alternatives.

C.3 Cost to the State

This method results in the project with the lowest overall cost to the State being the preferred alternative. "Overall cost" is simply a summation of all the costs to Caltrans (project alternative costs) and costs to the traveling public. The cost to the traveling public would include traffic delay costs (if known) and collisions over the design life of the project. Though the Cost to the State and Net Value methods are similar value measurement calculations, they state the value differently. The Cost to the State method sums all the project costs (construction, right-of-way, environmental, and maintenance) and costs to the traveling public (collisions and delay over the life of the project). The Cost to the State method is calculated as follows:

$$\text{Cost to the State} = \text{All Project Costs} + (\text{Collision Costs} + \text{Delay Costs})_{\text{Design life}}$$

The difference between the Cost to the State and Net Value methods is that the Net Value method subtracts the project costs from the benefits to the traveling public (the difference in the collisions between the No-Build and the alternative plus the reduced delay costs). The Cost to the State and Net Value methods should result in similar findings.

The Cost to the State method is typically not appropriate for a DSDD because it uses the overall cost of a project and all its future impacts on the State, whereas the DSDD focuses on whether it's justifiable for a project to meet an individual standard. The cost to meet the standard and the effect of the nonstandard feature on collisions is lost in the overall costs and impacts of the project; therefore, the Cost to the State method is more appropriate for using the HSM to analyze project alternatives.

Pros

- It measures the value of a project without the order of magnitude issue discussed with the Net Value method.
- It can be used when no benefits can be calculated when comparing to the No-Build alternative, since it looks only at the cost of the alternative plus the costs of the collisions and the expected delay of the alternative.
- Provides the best economic method for projects where the alternative increases the collisions over the no-build alternative, such as adding a new intersection or a new ramp to an interchange. There are many projects with a valid purpose-and-need that could result in an increase in collisions, or negative safety benefit, and B/C ratios since they don't work with negative benefits.
- It compares total alternative costs and benefits in dollars.
- It favors the project alternative that has the least overall cost to the State.

Cons

- It requires the calculation of the dollar value of benefits of collision reduction; Caltrans has not typically been evaluating projects in this manner.
- It may favor higher cost alternatives.

C.4 Benefit to Cost Ratio

This method is used to determine which alternative provides the greatest dollars of benefit per each dollar invested. The Benefit to Cost (B/C) Ratio method is calculated as follows:

$$Benefit\ to\ Cost\ Ratio = \frac{Benefit}{Cost}\ or\ \frac{B}{C}\ (see\ Figure\ 3\ below)$$

If the safety analysis of a nonstandard feature or project alternative concludes that the benefits are less than its initial cost, or $B/C < 1.0$, the approval authority may conclude that achieving the standard or the alternative is not a worthwhile investment because the long-term benefits do not outweigh its initial costs. There is no established B/C ratio threshold value that once reached means the alternative is a good economic value.

The project alternative that utilizes the dollars spent the most effectively is the alternative that has the highest benefit to cost ratio.

The B/C Ratio method for a DSDD is calculated by using the benefit associated with the standard feature (i.e., the change in collisions over the design life by meeting the standard(s)) divided by the additional costs to meet the standard(s). The B/C Ratio is calculated as follows:

$$\frac{B}{C} = \frac{Benefits_{Standard\ feature}}{Additional\ cost\ to\ meet\ the\ Standard}$$

Since projects across California differ in their purpose-and-need, context, community concerns, geometric or operational features, etc., there is no set minimum B/C Ratio that guarantees an investment is a good value. The DSDD approval authority determines the appropriate B/C Ratio that supports the additional investment while considering the additional project issues, factors, and concerns.

Note that the B/C Ratio method presented in this document is different than the California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C) that is available from the Division of Transportation Planning’s Office of Data Analytics Services, Transportation Economics Branch[10]. The B/C Ratio method presented in this document is applicable for projects in the PA&ED and PS&E project delivery phases.

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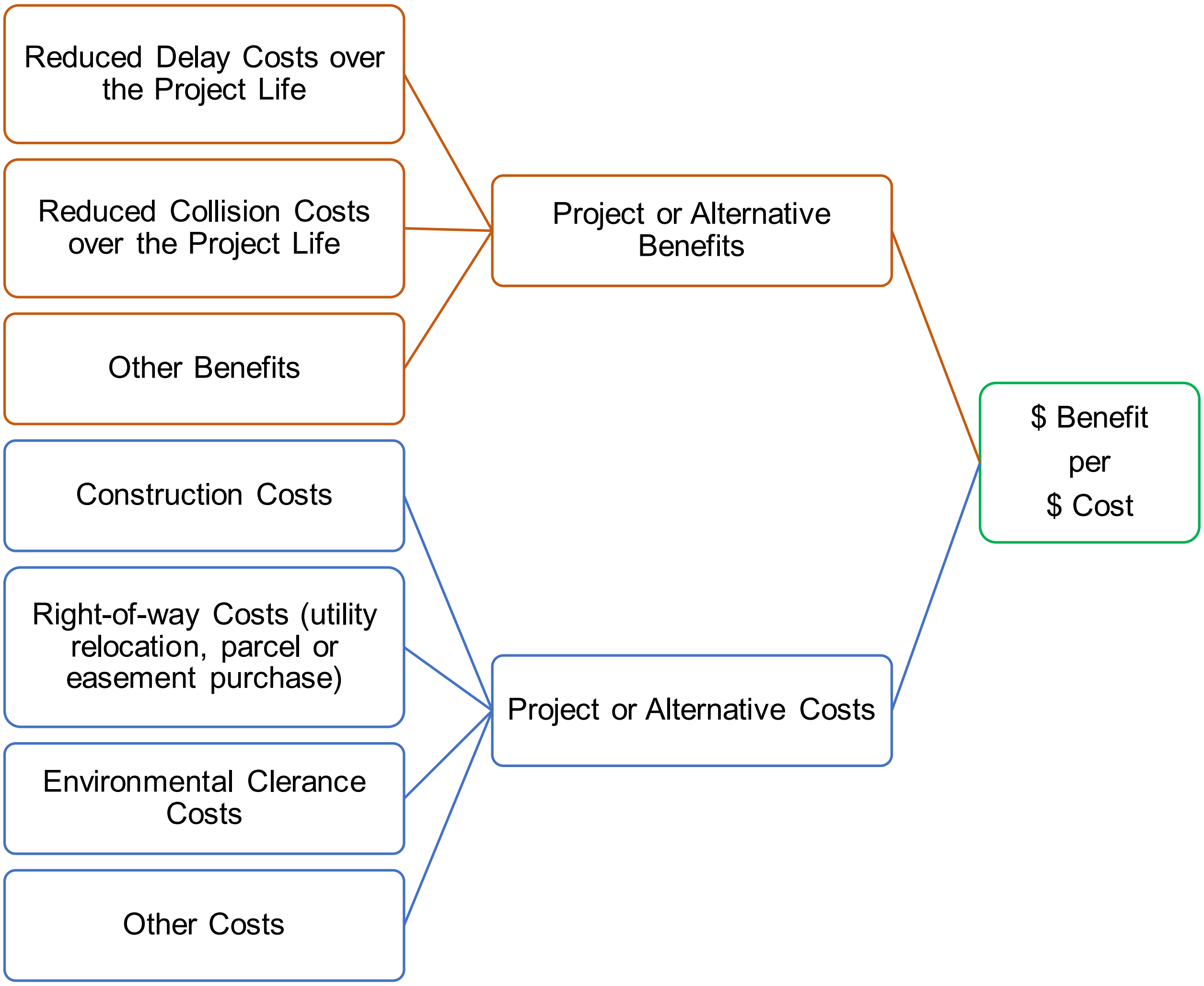
[10] https://dot.ca.gov/programs/transportation-planning/division-of-transportation-planning/data-analytics-services/transportation-economics

Figure 3 – Benefit to Cost Ratio Factors



Pros

- It compares dollars of alternative costs to dollars of alternative benefits.
- It compares dollars required to meet a standard design to dollars of standard design benefits.
- It is easy to determine the alternative that utilizes the dollars the most efficiently.

Cons

- It requires the calculation of the dollar value of benefits of collision reduction.
- It only works when a safety benefit can be calculated (i.e., proposed alternatives reduce the number of collisions when compared to the existing or No-Build condition).
- It can be open to subjectivity due to the lack of guidance in determining an appropriate threshold.