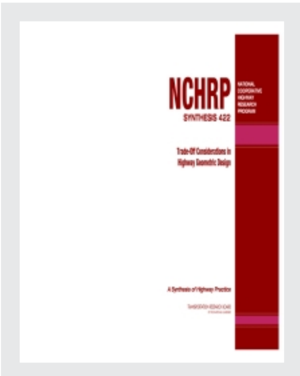

Trade-Off Considerations in Highway Geometric Design

DETAILS

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Trade-Off Considerations in Highway Geometric Design

A Synthesis of Highway Practice

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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Trade-Off Considerations in Highway Geometric Design

A Synthesis of Highway Practice

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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FOREWORD

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Gail R. Staba
Senior Program Officer
Transportation Research Board

This synthesis describes the processes that transportation agencies currently use to evaluate geometric design trade-offs between competing interests. It also highlights existing key publications on conventional approaches, context-sensitive solutions/context-sensitive design, and performance-based approaches, as well as gaps in information or analysis processes available to support design decisions. The audience for this report includes practitioners in transportation project development and delivery.

Information used in this study was acquired through a review of the literature and surveys.

Paul W. Dorothy, White Star Engineering Consultants, Worthington, Ohio, with assistance from Stephen L. Thieken, Burgess & Niple, Inc., Columbus, Ohio, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

TRADE-OFF CONSIDERATIONS IN HIGHWAY GEOMETRIC DESIGN

SUMMARY

AASHTO's *A Policy on Geometric Design of Highways and Streets* (commonly called the *Green Book*) is at the core of the conventional approach to highway design, and its design criteria are based on a large body of research and empirical data relating driver and vehicle performance to geometric characteristics. However, fewer new alignment roadways are being constructed and much more effort is being directed toward improving and reconstructing our existing infrastructure. Especially in urban areas, there is a much greater emphasis on the need for multimodal transportation solutions that fit as seamlessly as possible into an established context.

The 1990s began a greater focus on flexibility in highway design. As more designers begin to understand that the *Green Book* is not intended to impose rigid standards that artificially limit design options for a project, the use of appropriate flexibility in design has increased. To fully utilize that flexibility, the challenge to designers is to find solutions that balance often-competing objectives. Thus, more designers are beginning to see that design is a series of trade-offs and not simply a rigid application of design standards.

The goal of this Synthesis was to discover what processes transportation agencies are currently using to evaluate design trade-offs between competing interests. The report also attempts to highlight any existing gaps in information or analysis processes available to support the design decision. The ability to adequately identify trade-offs associated with design decisions and strike a balance between competing factors is critical to developing transportation projects that maintain safety and mobility while preserving the scenic, aesthetic, historic, social, and environmental resources of a community.

This synthesis is based on a survey distributed to 52 state transportation agencies (STAs), which resulted in responses from 43 agencies: 41 STAs, the District of Columbia, and Puerto Rico. In addition, a literature review focused on key publications outlining the conventional approach to design, as well as the newer context-sensitive solutions/context-sensitive design (CSS/CSD) and performance-based planning approaches. It also presents publications that outline complimentary fields that can be used to evaluate trade-offs, such as value engineering, choosing by advantages, risk analysis, and management and safety. Rather than an exhaustive literature search on a single topic area, the synthesis attempts to present an overview of the wide range of techniques available from the highway design and related fields and how they relate to trade-off analysis.

One of the key issues that the survey identified was that few STAs have codified procedures for evaluating trade-offs in highway geometric design. Based on the input received, the agencies surveyed generally had to rely on engineering judgment when conducting trade-off analyses. Most agencies evaluate trade-offs during preliminary engineering or environmental clearance. However, several agencies pointed out that frequently trade-offs are not raised until a design is nearly complete, often because of a lack of available design resources and decision makers in the predesign period. However, the later in the project development process trade-off decisions are made, the more limited the flexibility in dealing with them becomes.

Eleven typical categories of trade-offs were identified for inclusion in the survey instrument: (1) access management, (2) cost, (3) environmental issue, (4) historic impact, (5) human factors/driver expectancy, (6) operational efficiency, (7) right-of-way (ROW) availability, (8) safety, (9) schedule, (10) social concerns, and (11) tort liability exposure. STAs overwhelmingly identified safety as the trade-off most used as justification for design decisions. Cost and environmental issues are also frequently used to justify design decisions.

Approximately half of the STAs believed that there were gaps, problems, or missing components in their procedures and tools for evaluating design trade-offs. Some of the concerns identified were associated with a lack of formal guidance and procedures, which force STAs to rely on engineering judgment. Weaknesses of this approach are limitations associated with inexperienced staff, inconsistencies associated with informal practices, failure to adequately identify and consider appropriate trade-offs, and inconsistencies in documentation of decisions. Conversely, those agencies that did not believe there were gaps often pointed to processes and policies that, when followed, minimized gaps.

Approximately three-quarters of the agencies did not have risk prediction tools or techniques to help balance competing interests in the design process. Those that did have tools in place almost all used ones that combine a mixture of qualitative and quantitative analyses.

Approximately half of STAs have some tools and training to assist designers in evaluating trade-offs in the design selection process. Common tools identified are the *Highway Safety Manual*, the Interactive Highway Safety Design Model, Roadside Safety Analysis Program, value engineering, crash history, life-cycle cost analysis, and a design policy manual. However, only five agencies have developed specific performance goals regarding the evaluation of trade-offs.

Shoulder width was overwhelmingly the controlling criterion most often associated with a design exception request. Other controlling criteria are horizontal alignment, vertical alignment, and lane width. None of the respondents selected the controlling criterion of structural capacity, and several respondents added notes to the survey responses that this criterion would never be considered.

Approximately three-quarters of the agencies had no plans to reevaluate how trade-offs are handled in the design selection process in the next 6 to 12 months. Approximately 90% of the agencies had no plans to reevaluate how design exceptions are handled over the same period.

To evaluate the trade-offs associated with design, the designer's understanding of the basic controls and criteria associated with each element of the design is important. Although the *Green Book* provides little guidance on evaluating these trade-offs, it does establish the framework from which most controls and criteria are derived. For many situations, there is sufficient flexibility within the design criteria to achieve a balanced design and still meet minimum values.

CSS and CSD both consider the overall context within which a transportation project fits. The conventional approach to design does not emphasize an interdisciplinary approach, whereas the CSS/CSD approaches do. As the design process evolves, issues that do not center on design criteria become more important to determining the ultimate success of a design. This increases the need to identify trade-offs associated with design decisions accurately and completely and strike a balance between the competing factors in an interrelated decision-making process. CSS and CSD are excellent tools for providing structure to the compromise and trade-off process.

Several other closely related fields may offer insight into how to structure trade-offs to ensure the best decisions. Many of the tools, techniques, and processes currently utilized as part of the transportation field can be adapted for use in trade-off analysis, and some agencies have begun to incorporate them into everyday operations. These include performance-based planning, value engineering, choosing by advantages, project risk analysis, risk and reliability analysis, and risk management.

Promoting safety and safe travel is at the core of all transportation planning and design. The basic principles and guidelines that influence much of what happens in project development are founded on professional principles of encouraging safe design. As such, trade-offs may influence the safety potential of an alternative. Several key areas provide insight into how to address these trade-offs: organizational accident analysis and prediction, safety-conscious planning, Road Safety Audits, the interactive highway safety design manual, and the new *Highway Safety Manual*.

Preparation of this synthesis revealed that there are further research needs associated with evaluating trade-offs in highway geometric design. Several topics emerged as areas of interest for future study, including a formal process for evaluating trade-offs, risk prediction tools, tools for evaluating trade-offs, performance goals, online resources for the *Green Book*, impact of design consistency, the *Highway Safety Manual*, integration of project and system level trade-offs, and self-enforcing design.

CHAPTER ONE

INTRODUCTION

BACKGROUND

The conventional approach to roadway design has evolved from design methods that were first codified in the 1930s with the publication of *A Policy on Highway Classification* (1938). AASHTO's *A Policy on Geometric Design of Highways and Streets* (commonly called the *Green Book*) (*1*) is at the core of this conventional approach, and its design criteria are based on a large body of research and empirical data relating driver and vehicle performance to geometric characteristics. However, this guidance evolved in a time when America had embarked on building what is now one of the most extensive and advanced highway networks in the world. As such, much of the focus on the guidance was designing safe and efficient high-speed freeways and highways, which shows in the success of the Interstate system.

Once the Interstate system was effectively completed, the design focus began to shift. Fewer new alignment roadways are being constructed, and much more effort is being directed toward improving and reconstructing our existing infrastructure. Especially in urban areas, there is a much greater emphasis on the need for multimodal transportation solutions that fit as seamlessly as possible into an established context. Simply put, what was cost-effective and efficient at the time design criteria were established may be less so today and can vary over time.

The 1990s began to see a greater focus on flexibility in highway design, as designers faced increased numbers of vehicles on the nation's highways, constrained rights-of-way (ROWs), increased importance of public involvement, neighborhood and historic preservation requirements, community and economic development, environmental sensitivity, and concern for bicyclists and pedestrians (*2*). When Congress passed the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991, in addition to safety, it emphasized the importance of good design that is sensitive to its surrounding environment, especially in historic and scenic areas. Section 1016(a) of ISTEA states, "If a proposed project…involves a historic facility or is located in an area of historic or scenic value, the Secretary may approve such project…if such project is designed to standards that allow for the preservation of such historic or scenic value and such project is designed with mitigation measures to allow preservation of such value and ensure safe use of the facility."

As more designers begin to understand that the *Green Book* is not intended to impose rigid standards that artificially limit design options for a project, the use of appropriate flexibility in design has increased. To fully utilize that flexibility, the challenge to designers is to find solutions that balance often-competing objectives. As such, more designers are beginning to see that design is a series of trade-offs and not simply a rigid application of standards.

Current highway geometric design processes require establishment of fundamental design controls (e.g., area type, terrain, functional classification, traffic volume) and selection of design speed. The process then becomes dimensionally based, with minimums, maximums, and ranges in design values directly derived from tables, charts, and equations. Projects must also meet performance goals defined in the Purpose and Need (P&N) statement. Design criteria, state transportation agency (STA) performance goals, and stakeholder interests or goals may be in conflict. This synthesis will discover what processes STAs are currently using to evaluate design trade-offs between competing interests, including cost, operational efficiency, ROW availability, environmental issues, social concerns, and specific safety measures. This may provide a strategic first step toward development of design processes that incorporate risk prediction tools and technologies to balance competing interests.

Common examples of trade-offs in highway geometric design include the following:

- Reducing the width of roadway travel lanes to provide dedicated bike lanes;
- Reducing the width of roadway travel lanes to provide an outside shoulder width sufficient to refuge a disabled vehicle;
- Reducing the width of roadway shoulders to reduce the necessary ROW based on cost, environmental, or historic preservation concerns;
- Reducing shoulder width on long span bridges to reduce overall project cost;
- Not providing a median barrier to increase aesthetics and community linkages;
- Increasing overhead bridge length to increase aesthetics, community linkages, and feeling of security for pedestrians; and

- Using a tree-lawn to provide a buffer for an adjacent pedestrian or multiuse path.

Roadway planning and design are discretionary processes, involving professionals assessing trade-offs among the needs of the project, including physical condition, operational efficiency, safety, access, costs, environmental impacts, and community concerns. To support these discretionary decisions from claims of negligence, the designers need adequate documentation to show that they exercised this discretion by carefully evaluating alternatives and weighing the important trade-offs.

KEY LEGISLATIVE/POLICY INPUTS

Several key legislative or policy decisions have directly affected the increased need to evaluate trade-off considerations in highway geometric design. The first of these are Section 4(f) of the Department of Transportation Act of 1966, which provided the mandate to protect properties, and the National Environmental Policy Act (NEPA) of 1969, which set environmental goals and policies to complement Section 4(f). All federally funded projects have three classes of action that require detailed alternative justification:

- Environmental impact statement
- Environmental assessment
- Categorical exclusion.

Other initiatives followed. In 1991, the ISTEA created a National Highway System (NHS) consisting of the Interstate system, roads important to national defense, and roads that provide intermodal connectivity. It required that transportation projects consider both environmental impacts and quality of life. Road design and construction had to focus on the preservation of the natural environment, social and environmental impacts, and preservation of historic property and scenic sites. Furthermore, engineering designs had to carefully balance these social, environmental, and cultural issues with the traditional commitment to safety and mobility. This initiative would later become the context-sensitive solutions/context-sensitive design (CSS/CSD) initiative. In 1998, the Transportation Equity Act for the 21st Century (TEA-21) focused on improving traffic safety, decreasing congestion, protecting and enhancing communities and the natural environment, and advancing America's competitiveness and economic growth both domestically and internationally. In 2005, the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was passed. It encourages federal transportation agencies to perform project delivery and environmental reviews concurrently as opposed to sequentially and requires the transportation planning process to consider natural resources (*3*).

Thinking Beyond the Pavement, a national workshop held in 1998, was a pioneering step in CSS/CSD. The workshop identified seven qualities of excellence in transportation design and eight characteristics of the process that would yield excellence, all of which were termed principles of CSD (*4*). The outcome of this workshop was an acceleration of the integration of CSS/CSD principles into many state transportation agency policies and practices.

In the fall of 2006, AASHTO and FHWA jointly sponsored two national meetings to examine the implementation of CSS/CSD in transportation agencies. The outcome of these meetings was a refinement of the definition and principles of CSS/CSD, establishment of joint AASHTO/FHWA strategic goals, and an action plan to further the implementation of CSS/CSD in transportation agencies. The revised definition developed for CSS is a "collaborative, interdisciplinary approach that involves all stakeholders in providing a transportation facility that fits its setting. It is an approach that leads to preserving and enhancing scenic, aesthetic, historic, community, and environmental resources, while improving or maintaining safety, mobility, and infrastructure conditions" (*5*). The updated CSS/CSD principles are as follows:

- Strive toward a shared stakeholder vision to provide a basis for decisions.
- Demonstrate a comprehensive understanding of contexts.
- Foster continuing communication and collaboration to achieve consensus.
- Exercise flexibility and creativity to shape effective transportation solutions, while preserving and enhancing community and natural environments (*5*).

The specific qualities of excellence in transportation design were updated to include the following:

- Establishes an interdisciplinary team early, including a full range of stakeholders, with skills based on the needs of the transportation activity;
- Seeks to understand the landscape, the community, valued resources, and the role of all appropriate modes of transportation in each unique context before developing engineering solutions;
- Communicates early and continuously with all stakeholders in an open, honest, and respectful manner, and tailors public involvement to the context and phase;
- Utilizes a clearly defined decision-making process;
- Tracks and honors commitments through the life cycle of projects;
- Involves a full range of stakeholders (including transportation officials) in all phases of a transportation program;
- Clearly defines the purpose and seeks consensus on the shared stakeholder vision and scope of projects and activities, while incorporating transportation, community, and environmental elements;

- Secures commitments to the process from local leaders;
- Tailors the transportation development process to the circumstances and uses a process that examines multiple alternatives, including all appropriate modes of transportation, and results in consensus;
- Encourages agency and stakeholder participants to jointly monitor how well the agreed-upon process is working, to improve it as needed, and when completed, to identify any lessons learned;
- Encourages mutually supportive and coordinated multimodal transportation and land use decisions; and
- Draws upon a full range of communication and visualization tools to better inform stakeholders, encourage dialogue, and increase credibility of the process (*5*).

In addition, it was emphasized that CSS/CSD leads to outcomes that—

- Are in harmony with the community and preserve the environmental, scenic, aesthetic, historic, and natural resource values of the area;
- Are safe for all users;
- Solve problems that are agreed upon by a full range of stakeholders;
- Meet or exceed the expectations of both designers and stakeholders, thereby adding lasting value to the community, the environment, and the transportation system; and
- Demonstrate effective and efficient use of resources (e.g., people, time, budget) among all parties (5).

OBJECTIVES AND FOCUS

The goal of this synthesis is to identify and compile existing practices for assessing trade-offs in design and the processes for selecting and approving a specific design. The report also attempts to highlight any existing gaps in information or analysis processes available to support the design decision. The audience for this report is intended to be practitioners involved in the project development and delivery process.

Data to support this investigation came from both published literature and a survey of STAs. The literature review focused on identifying key publications that represent—

- Existing STA, other highway provider, and municipality practices in considering trade-offs in highway geometric design decisions, including design exceptions;
- The body of work used to evaluate risk and reliability (trade-offs) in other types of civil works projects; and
- Other relevant processes or procedures which could be applied in total or in part to the process of evaluating trade-offs in highway geometric design.

The synthesis report includes a survey of existing STA practice used to evaluate design trade-offs between competing interests, including cost, operational efficiency, ROW availability, environmental issues, social concerns, and specific safety measures. In addition to a survey of existing practice, the survey gathered information on the following:

- Respondent definition and measurement of risk
- Gaps, strengths, and weaknesses in the design selection process relative to trade-offs
- Any transportation agency performance goals developed, evaluated, or met
- Roles and responsibilities of decision-making participants
- Examples of successful practices
- How statewide program criteria affect project design
- Training tools for designers that focus on design decisions

SCOPE AND CONTENT

This synthesis is based on information collected during a detailed literature search and from documents made available from selected STAs. In addition, a survey exploring the evaluation of trade-offs in the design selection process, risk, tools and training, agency experience, design exception process, and the future was distributed to 52 STAs, including the District of Columbia and Puerto Rico. Forty-three completed surveys responses were received from 41 states, the District of Columbia, and Puerto Rico. Additional insight, gained from the author's personal experiences and through contacts, is also shared as appropriate.

Chapter one presents the background for the synthesis, including the genesis of the synthesis, the material generated by the project panel, and the objectives and scope of work. Chapter two presents the information gathered through the synthesis literature search. This chapter presents information regarding—

- Conventional process of evaluating trade-offs using the *Green Book*
- Nominal and substantive safety
- Impact of the design exception process on the analysis of trade-offs
- Impact of the use of flexibility in highway design
- CSS/CSD, including background, needed data and inputs to the CSS/CSD process, treatment of basic design control, and processes for alternatives analysis and project documentation
- Performance-based design
- Value Engineering (VE), including background, processes, and the relation between VE and CSS/CSD
- Choosing by advantages
- Risk analysis and management, including basic concept of risk and risk management, project management

and risk and reliability analysis methods of dealing with risk, and the psychology of risk perception

- Influence of safety in the acceptance of trade-offs, including organizational accidents, safety conscious planning, road safety audits, the *Interactive Highway Safety Design Manual* (IHSDM), the *Highway Safety Manual* (HSM), and SafetyAnalyst.

Chapter three presents a brief summary of the results of the detailed survey. This discussion is not meant to be all-inclusive, but simply provides an overview of the responses received regarding evaluation of trade-offs in the design selection process, risk, tools and training, agency experience, design exception process, and the future. Chapter four presents the concluding remarks that reflect on the issues identified and discussed in the synthesis report. References and a bibliography of useful citations that were not specifically mentioned in the text are included. Finally, two appendixes present the STA survey instrument (Appendix A) and a summary of STA survey responses (Appendix B).

CHAPTER TWO

LITERATURE REVIEW

This chapter presents the information gathered through the synthesis literature search. It starts with a focus on the conventional process of evaluating trade-offs using the *Green Book*, explores the concept of nominal and substantive safety, how the design exception process affects the analysis of trade-offs and examines the impact of flexibility in highway design. Next, the concepts of CSS/CSD are explored, with discussions centered on the background of CSS/CSD, needed data and inputs to the CSS/CSD process, how the basic design controls are treated in CSS/CSD, the process for alternatives analysis, project documentation and decision processes, and identification of case studies. The following section discusses performance-based design and VE; the VE section provides a background on VE, expands on the relation of VE to CSS/CSD, and outlines the VE process. Next, the process of choosing by advantages is outlined, followed by a section dealing with risk analysis and management. The section on risk examines the basic concept of risk and risk management, project management and risk and reliability analysis methods for dealing with risk, and the psychology of risk perception. The final section examines the influence of safety in the acceptance of trade-offs, with discussions focused on lessons from the field of organizational accidents, safety-conscious planning, and road safety audits, with overviews of the IHSDM, HSM, and the software tool SafetyAnalyst.

CONVENTIONAL APPROACH

The *Green Book*

Design criteria, established through years of practice and research, form the basis on which highway designers strive to balance cost, safety, mobility, social and environmental impacts, and the needs of a wide variety of roadway users. The national policy for geometric design is presented in the AASHTO's *A Policy on Geometric Design of Highways and Streets* (or *Green Book*) (*1*). It is important to note that the *Green Book* criteria are not all based on robust scientific based safety analysis. However, use of the *Green Book* design standards does promote design consistency, which has an impact on safety. Uniform application of these standards creates roadways that conform to the driver's expectations by providing positive guidance through a variety of visual cues.

At the time of this synthesis, the current edition of the *Green Book* is the 2004 edition, and it forms the basis for most of the design criteria utilized by STAs. The *Green Book* offers design policies and guidelines, not standards. For each design element, AASHTO typically provides a range of acceptable values, from the absolute minimum value to a more desirable target value. For an AASHTO guideline to become a standard, it must be adopted by an STA. Most states have adopted standards toward the middle or upper end of the AASHTO ranges (*6*).

AASHTO, formed in 1914 as the American Association of State Highway Officials (AASHO) gave STAs a unified voice to improve road quality. Although the fundamental principles of geometric design were discussed in engineering texts as early as 1921, it was not until 1938–1944 that AASHO published seven documents that formally outlined policies on certain aspects of geometric design. These seven documents were bound together as the *Policies on Geometric Design* (*7*) in 1950. The policies were amended in 1954 with the publication of *A Policy on Geometric Design of Rural Highways* (or *Blue Book*) (*8*), which was updated in 1965 (*9*). The urban environment was covered in the 1957 *A Policy on Arterial Highways in Urban Areas* (*10*) and updated in 1973 with *A Policy on Design of Urban Highways and Arterial Streets* (*11*). In addition, AASHTO developed *Geometric Design Standards for Highways Other Than Freeways* (*12*) in 1969. All of these publications were collected together with the first publication of the *Green Book* in 1984 (*13*), which was subsequently updated in 1990 (*14*), 1994 (*15*), 2001 (*16*), and 2004 (*1*). The design criteria created by AASHO and AASHTO have served as the basis for nearly a century of highway geometric design practice.

In the foreword, the *Green Book* outlines the intent of the guidance.

> The intent of this policy is to provide guidance to the designer by referencing a recommended range of values for critical dimensions. It is not intended to be a detailed design manual that could supercede the need for the application of sound principles by the knowledgeable design professional. Sufficient flexibility is permitted to encourage independent designs tailored to particular situations. Minimum values are either given or implied by the lower value in a given range of values. The larger values within the ranges will normally be used where the social, economic and environmental impacts are not critical (*1*).

Updates to the *Green Book* have attempted to provide guidance regarding the necessity to consider the needs of nonhighway users and the environment as well during benefit-cost analysis. The authors acknowledge that this adds to the complexity of the analysis, but emphasize that this broader approach will allow for both the need for a given project and the relative priorities among various projects to be taken into account. In addition, this broader approach allows the goal of cost-effective design not merely to give priority to the most beneficial individual projects, but also to provide the most benefits to the highway system of which each is a part—a system solution.

Trade-off Considerations

The broad overview of trade-off considerations contained in the *Green Book* points out that the guidance is intended to provide operational efficiency, comfort, safety, and convenience for the motorist, while taking into consideration environmental quality. Further, the effects of the various environmental impacts can be mitigated by thoughtful design processes. This principle, coupled with that of aesthetic consistency with the surrounding terrain and urban setting, is intended to produce highways that are safe and efficient for users, acceptable to nonusers, and in harmony with the environment. The emphasis is on obtaining a balance between all geometric elements, as far as economically practical, to provide safe, continuous operation at a speed likely to be observed under the normal conditions for a given roadway for a vast majority of motorists. However, its design guidelines may be overly conservative for some conditions, often based on dated studies from a time when tires, braking systems, pavements, and vehicle dimensions were less forgiving than today (*6*). This is confounded by the aging of the driver population with correspondingly reduced capabilities. The *Green Book* follows the philosophy that above-minimum design values be used where feasible. Further, there is a belief that a linear relationship exists between increased magnitude of these minimum design values and the project "quality" or benefits (*17*). However, in view of the numerous constraints often encountered, practical values need to be recognized and used as needed (*18*).

The guidance speaks to the evaluation of trade-offs in conceptual terms and does not provide specific cause-and-effect examples. Further, as the guidance has developed, much of the background material regarding how standards have been developed has been removed, making it more difficult for practitioners to establish these relationships. Chapter three of the *Green Book*, which deals with elements of design, will be taken as an example to illustrate how the potential impact of trade-offs associated with the common elements of design of sight distance, superelevation, horizontal alignment, and vertical alignment are presented in the guidance.

- *Sight Distance.* With regard to sight distance, it is important that the designer provide sight distance of sufficient length that drivers can control the operation of their vehicles to avoid striking an unexpected object in the traveled way. It points out that although greater lengths of visible roadway are desirable, the sight distance at every point along a roadway should be at least that needed for a below-average driver or vehicle to stop. This establishes the minimum criteria that must be met with regards to sight distance, but does not provide information on potential trade-offs.
- *Superelevation.* The guidance points out that the design of roadway curves need to be based on an appropriate relationship between design speed and curvature and on their joint relationships with superelevation and side friction. Again, no guidance is given on how to evaluate this appropriate relationship.
- *Horizontal Alignment.* As with most sections, the guidance is focused on the impact of design decisions on safety. It points out that adjustments to the highway cross-section or alignment may be necessary in situations in which there are sight obstructions on the inside of curves or the inside of the median lane on divided highways. The guidance does identify a generalized approach to evaluating the trade-offs associated with providing horizontal sight distance on a curve. It acknowledges that because of the many variables in alignment, in cross section, and in the number, type, and location of potential obstructions, specific study is usually needed for each individual curve. The guidance further lists several general controls that need to be followed for horizontal alignment, but does not provide specific guidance regarding the importance of each.
- *Vertical Alignment.* As with horizontal alignment, the guidance points out that the major control for safe operation on crest vertical curves is the provision of ample sight distances for the design speed. It explains that although research has shown that vertical curves with limited sight distance do not necessarily experience safety problems, it is recommended that all vertical curves be designed to provide at least the stopping sight distance listed in the guidance. The guidance lists several general controls that could be followed for horizontal alignment, but does not provide specific guidance regarding the importance of each.
- *Combination of Horizontal and Vertical Alignment.* The guidance lists general controls for combinations of horizontal and vertical alignment, but provides no guidance on how to evaluate trade-offs that may arise regarding them.

An example of more specific recommendations for potential deviation from desirable criteria is associated with lane widths. Although the guidance does not specifically address the evaluation of trade-offs, it does provide guidance under which conditions different design values can be used. The guidance states,

> Although lane widths of 3.6 m [12 ft.] are desirable on both rural and urban facilities, there are circumstances where lanes less than 3.6 m [12 ft.] wide should be used. In urban areas where pedestrian crossings, right-of-way or existing development become stringent controls, the use of 3.3 m [11 ft.] lanes is acceptable. Lanes 3.0 m [10 ft.] wide are acceptable on low-speed facilities, and lanes of 2.7 m [9 ft.] wide are appropriate on low-volume roads in rural and residential areas. In some instances, on multilane facilities in urban areas, narrower inside lanes may be utilized to permit wider outside lanes for bicycle use. In this situation, 3.0 m to 3.3 m [10 ft. to 11 ft.] lanes are common on inside lanes with 3.6 m to 3.9 m [12 ft. to 13 ft.] lanes utilized on outside lanes (*1*).

Trade-off on Criteria

To evaluate the trade-offs associated with a design, the designer must understand the basic controls and criteria associated with each element of the design. Although the *Green Book* provides little guidance on evaluating these trade-offs, it does establish the framework from which most controls and criteria are derived. The following critical design controls affect the flexibility of the criteria and, thus, the ability to undertake trade-offs:

- Highway functional classification
- Design speed
- Acceptable operational level of service of the facility
- Physical characteristics of the design vehicle
- Performance of the design vehicle
- Capabilities of the typical driver
- Existing and design traffic demand (*18*).

During the past two decades, there has been considerable research on all aspects of geometric design affecting how roadways are designed, how they operate, and ultimately, their safety. A limitation to the potential application of this research is the sheer volume of new information; the following new publications became available in this period (*19*):

- *Older Driver Highway Design Handbook* (FHWA 1995)
- *Highway Capacity Manual* (TRB 2010)
- *Guide for the Development of Bicycle Facilities* (AASHTO 1999)
- *Traffic Safety Toolbox: A Primer on Traffic Safety* (ITE 1999)
- *Access Management Manual* (TRB 2003)
- *Access Management Guidelines for Activity Centers* (TRB 1992)
- *Impacts of Access Management Techniques* (TRB 1999)
- *Driveway and Street Intersection Spacing* (TRB 1996)
- *HOV Systems Manual* (TRB 1998)
- *Design and Safety of Pedestrian Facilities* (ITE 1998)
- *Building a True Community* (U.S. Access Board 2001)
- *Interactive Highway Safety Design Model* (FHWA 2010)
- *Highway Safety Manual* (AASHTO 2010)
- *Guide for Achieving Flexibility in Highway Design* (AASHTO 2004)
- *Flexibility in Highway Design* (FHWA 1997)
- *Designing Walkable Urban Thoroughfares* (ITE 2010).

Additional new research into the basic building blocks of the *Green Book* such as stopping sight distance, superelevation, and, most important, design speed may also significantly affect design criteria. Further, within the CSD community there is strong concern that the basic concept of functional roadway classifications has limitations (*19*).

Nominal and Substantive Safety

Many of the criteria called for by the *Green Book* are based on the concept of providing adequate safety through the use of design controls and criteria. To adequately evaluate trade-offs associated with deviations from these design standards requires an understanding of how safety is affected by a particular control or criterion. However, the guidance presents safety as an absolute, not a continuum. To understand this concept, we will examine the concepts of nominal safety and substantive safety introduced by Hauer (*20*).

Nominal safety refers to a design or alternative's adherence to design control or criteria. A design that meets a design criterion is said to be nominally safe, whereas one that does not is nominally unsafe. It is important to note that these criteria are also based on the concept of providing a design that meets the needs of "most" drivers—that allows for most drivers to operate both legally and safely and is consistent with accepted design practices. Substantive safety, in contrast, refers to the actual performance of a highway or facility as measured by its crash experience (e.g., number of crashes per mile per year, consequences of those crashes as specified by injuries, fatalities, or property damage, etc.). A road or road segment is then determined to be substantively safe or unsafe based on its actual crash experience as compared with some relative expectation. It is possible to have a road that is nominally safe (i.e., all the geometric features meet design criteria) but substantively unsafe (i.e., there is a known or demonstrated high crash problem). Similarly, not all roads that are nominally unsafe are substantively unsafe. Thus, designs that do not meet the design criteria outlined in the *Green Book*, while nominally unsafe, may still be substantively safe.

Knowledge of the safety effects of design aids designers and stakeholders in making reasoned decisions and trade-offs involving safety. Substantive safety is a continuum, whereas nominal safety is an absolute (see Figure 1). Incremental difference in a design dimension (e.g., radius of curve, width of road, offset to roadside object) can be expected to produce an incremental, not absolute change in crash frequency or severity. This concept differs from the idea that a nominally unsafe design will automatically result in a substantive safety problem (*4*).

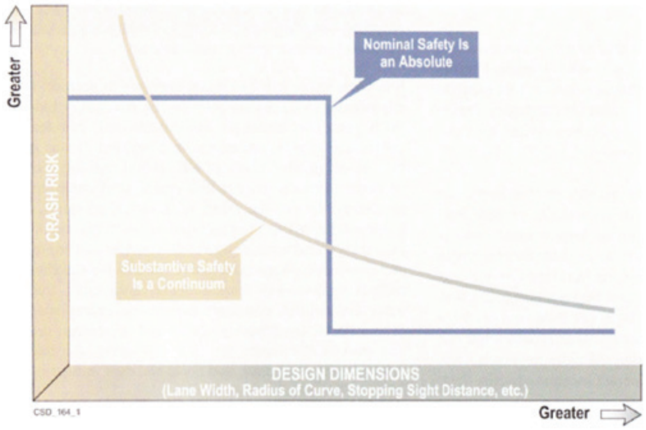


FIGURE 1 Comparison of nominal and substantive safety. *Source: NCHRP Report 480: A Guide to Best Practices for Achieving Context-Sensitive Solutions (4).*

Much research has been performed over the past 30 years to uncover the relationship of substantive safety to design. Many of the models are relatively new, and few agencies have well-established procedures for exercising these models to understand the safety impacts of varying design criteria. It is an unintended consequence that many working-level staff believe that standards equal safety and that no compromises can be accepted. This view holds even with design values that clearly are not related to design exceptions or to substantive safety (*21*). The basis for many design criteria has been removed from the discussion presented in the *Green Book*. As such, practitioners must perform research to determine which design values directly support substantive safety and which do not.

Not all crashes are the result of a geometric design or roadway issue. A study by Rumar (*21*) compared causes of crashes in both the United States and Great Britain with respect to the roadway, driver, and vehicle (see Figure 2). The results of the study show that only 3% of crashes are the result of the roadway environment alone, whereas 57% are related only to drivers and 2% only to vehicles. When interactions (roadway–driver, roadway–vehicle, and roadway–vehicle–driver) are accounted for, 34% of crashes are associated with road-related elements. However, 94% of crashes are associated with driver-related elements.

To empower design staff to evaluate the trade-offs associated with being flexible within design criteria, staff need to become more knowledgeable in not just the criteria, but the reasons for them (which may include safety, operations, maintenance, constructability, and other issues) and will need to address the rigidity in current criteria and design manuals. With respect to the former point, FHWA has developed a course to educate design staff on the functional basis of critical design criteria to enable informed decisions when applying engineering judgment and flexibility (see *Geometric Design: Applying Flexibility and Risk Management, National Highway Institute,* FHWA-NHI-380095).

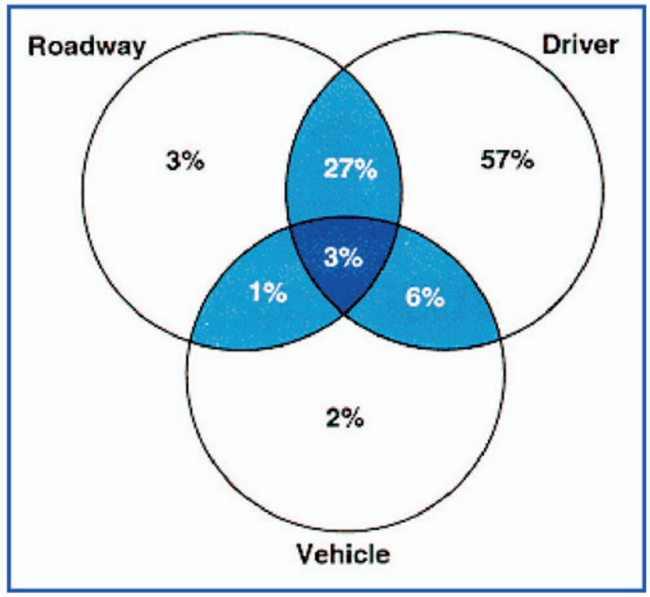


FIGURE 2 Venn diagram relating crash causes. *Source:* Rumar *(21)*.

Design Exceptions

Design criteria established through years of practice and research form the basis on which highway designers strive to balance competing needs for a roadway project. For many situations, the design criteria are flexible enough to achieve a balanced design and still meet minimum values. For various reasons, it is not always practical or desirable that a project meet each and every design criterion and standard. On occasion, designers encounter situations with especially difficult site constraints, and an appropriate solution may suggest the use of design values or dimensions outside the normal range established by a control or criterion. In such cases, a design exception may be considered. Before the final decision is made to accept a design exception, design alternatives and their associated trade-offs are evaluated through a deliberative process. Examining multiple alternatives provides a way to understand and evaluate the trade-offs. From the standpoint of risk management and minimizing tort liability, evaluating multiple alternatives demonstrates the complex, discretionary choices involved in highway design.

For projects on NHS routes, FHWA requires that all exceptions from accepted guidelines and policies be justified and documented in some manner, and requires formal approval for 13 specific controlling criteria. The process of justification and documentation is not required, but states that are exempted from FHWA oversight on non-NHS projects can follow it as well. The FHWA Federal-Aid Policy Guide identifies the following 13 controlling criteria as requiring formal design exceptions:

- Design speed
- Lane width

- Shoulder width
- Bridge width
- Structural capacity
- Horizontal alignment
- Vertical alignment
- Grade
- Stopping sight distance
- Cross slope
- Superelevation
- Vertical clearance
- Horizontal clearance (*22*).

Individual STAs have established other controlling criteria that may also apply to decisions regarding design exceptions. Further, STAs can use design exceptions on non-NHS routes.

This process establishes a clear understanding of the potential negative impacts of the decision to deviate from a design control or criteria. If the decision is made to go forward with a design exception, measures to mitigate or reduce the potential negative impacts need to be identified. Potential mitigation strategies associated with each type of design exception are listed in the FHWA *Mitigation Strategies for Design Exceptions* (*23*).

A design exception is a documented decision to design a highway element or segment of highway to design criteria that do not meet minimum values or ranges established for that highway or project. As discussed in the previous section, by definition, a design exception is the acceptance of a design that does not meet nominal safety for that criterion. Documentation of design exceptions is important to verify that sound engineering judgment and social/cultural impacts have been considered and that the proposed solution demonstrates an appropriate balance of these components. Further, a written design exception that illustrates that a flexible solution using sound engineering practices has protected the public's interest as a whole, avoids undue risk in liability. A typical design exception request includes the following:

- Description of existing highway conditions and proposed improvement project;
- Thorough description of the substandard feature(s), providing specific data identifying the degree of deficiency;
- Crash data for at least the latest 3-year period, indicating frequency, rate, and severity of crashes;
- Costs and adverse impacts that would result from meeting current design standards;
- Safety enhancements that will be made by the project to mitigate the effects of the nonstandard feature; and
- Discussion of the compatibility of the proposed improvement with adjacent roadway segments (*4*).

However, there is no formal priority when examining the trade-offs associated with respect to nominal safety of each of the 13 controlling criteria. There is no clear, quantifiable means of determining which controlling criteria are most important and how crash frequency varies with variation in each controlling criterion.

A study conducted by Stamatiadis et al. (*24*) examined crash exposure related to design exceptions filed in Kentucky from 1993 to 1998. Design exceptions were approved on 319 projects during the 8-year study period, an average of 40 per year. The majority of the projects associated with these design exceptions were bridge replacements (57%), roadway widening reconstruction (13%), and construction of a turning lane (9%). A total of 562 design exceptions were filed (an average of 1.8 per project), with the most common associated with design speed (34%), sight distance (12%), curve radius (12%), and shoulder width (11%). A crash analysis was performed to determine if there were any consequences associated with the design exceptions. This analysis showed that, with few exceptions, the use of design exceptions did not have a negative effect on highway safety.

Flexibility in Highway Design

The *Green Book* provides sound guidelines for many aspects of road design and construction. However, because the *Green Book* is a universally accepted roadway design guide, many of the guidelines it contains have come to be seen as rigid standards and its inherent flexibility has been neglected. To help overcome some of the limitations of the conventional approach to highway design as presented in the *Green Book*, FHWA produced *Flexibility in Highway Design* (*18*) in 1997 and AASHTO produced the *Guide for Achieving Flexibility in Highway Design* (*25*) in 2004. These guides do not attempt to create new standards; rather, they build on the flexibility in the current standards to identify opportunities to use flexible design as a tool to help sustain important community interests without compromising safety. This approach stresses the need to identify which sections of the standards are flexible and to understand the impacts of each standard on the effectiveness of the overall design. Further, the designer must become aware of local concerns of interested organizations and citizens. The designer must then balance the need to provide a safe, efficient transportation system that is able to conserve and even enhance environmental, scenic, historic, and community resources.

Flexibility in Highway Design was developed in conjunction with several other agencies and interest groups, including AASHTO, Bicycle Federation of America, National Trust for Historic Preservation, and Scenic America. The guidance was written for a target audience of highway engineers and project managers who want to learn more about the flexibility available to them when designing roads. It focuses on the flexibility already available within adopted state standards, often based on the *Green Book*, that allows designers to tailor their designs to the particular situations encountered in each highway project. It states that these standards often provide enough flexibility to achieve a design that both meets the objectives of the project and is sensitive to the surrounding environment. However, it points out that it is sometimes necessary for designers to look beyond the "givens" of a highway project and consider other options. This could be accomplished by utilizing the design exception process described previously, reevaluating planning decisions, or rethinking the appropriate design. The guidance points out that during the project planning, development, and design phases, designers and communities can work together to have the greatest impact on the final design features of the project. To facilitate understanding, the problems associated with the project are usually grouped into one or more of the following four categories: physical condition, operations, safety, and access. The guidance also notes that the flexibility available for highway design during the detailed design phase is limited by the decisions made at earlier stages of planning and project development, demonstrating the need to integrate the community into the process early in the project (*18*).

The *Guide for Achieving Flexibility in Highway Design* was developed to aid the designer in better understanding the reasons behind design processes, design values, and design procedures commonly used. It emphasizes that flexible design does not represent a fundamentally new process; instead, it focuses on identifying ways to think flexibly and identify the many choices and options available. The guidance outlines processes, tools, and techniques to understand and incorporate community interests into project development and to select appropriate design criteria to support flexible design. It provides an overview of key geometric elements, the models and assumptions used to develop design criteria, and a brief summary of the current knowledge regarding operational and safety effects of design. Finally, the guidance summarizes how designers can achieve flexibility while minimizing risk through open development and evaluation of multiple alternatives, assessment of trade-offs, and documentation of the final decisions (*25*).

CONTEXT-SENSITVE SOLUTIONS/CONTEXT-SENSITIVE DESIGN

FHWA defines CSS as a collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic, and environmental resources while maintaining safety and mobility. CSS considers the total context within which a transportation improvement project will exist. CSS principles include early, continuous, and meaningful involvement of the public and all stakeholders throughout the project development process (*26*).

CSD is defined as the project development process (including geometric design) that attempts to address safety and efficiency while being responsive to or consistent with the road's natural and human environment. It addresses the need for a more systematic and all-encompassing approach in project development that recognizes the interdependency of all stages and views them along a continuum. To achieve such balance, trade-offs among several factors are needed and are routinely made in most projects (*27*).

The conventional approach to design does not emphasize an interdisciplinary approach, whereas CSS/CSD approaches do. Over the years, the conventional process has become more structured and formalized and has attempted to include the need to balance trade-offs between strictly transportation requirements and other goals. As the design process evolves, consideration given to issues that do not center on design criteria becomes increasingly important to determining the ultimate success of a design. This increases the need to identify trade-offs associated with design decisions accurately and completely and strike a balance between the competing factors in an interrelated decision-making process.

Key steps in the CSS/CSD transportation decision-making process are as follows:

- Comprehensive, upfront identification of context
- Linked decision-making process to ensure that final solutions address the problems identified up front
- Stakeholder involvement early and often
- Use of multidisciplinary teams
- Comprehensive documentation to ensure that commitments are communicated and implemented throughout the process (*28*)

Figure 3 flowcharts North Carolina's CSS/CSD decision-making process.

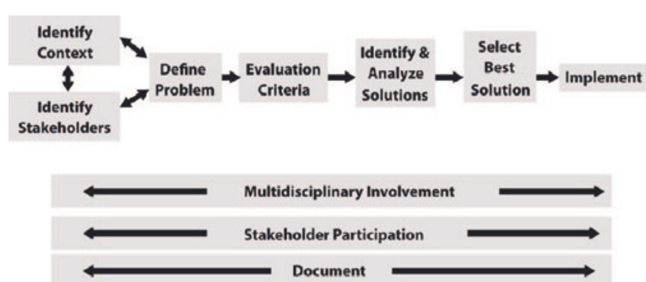


FIGURE 3 North Carolina's decision-making framework. *Source:* D'Ignazio and Hunkins *(29)*.

CSS/CSD focuses on identifying design problems in functional or performance terms and arriving at solutions that address them, instead of rote application of design standards. To develop these designs, the designer makes a series of trade-offs while balancing competing interests such as operational efficiency, safety, cost, serving multiple users, and achieving environmental sensitivity. CSS/CSD principles and practices provide a framework for designers to document the rationale for adjustments to guidelines or criteria to best satisfy the needs of the working environment. However, this creates a tension between the design consistency associated with the traditional *Green Book* approach and the flexible approach to roadway design associated with CSS/CSD.

Because successful projects require a level of compromise and trade-off, CSS/CSD are excellent processes for providing structure. In the end, key decisions will be documented, absolutely necessary design requirements will be met, appropriate flexibility in design will be implemented, and guidelines that can be applied for the betterment of other factors will be identified in a reasonable, defensible manner (*4*).

An agency may be reluctant to deviate from standards in the face of tort concerns, limited safety research, and project plan modifications. In the Washington State Department of Transportation's (WSDOT) early experiences, this was the case even when aesthetic, environmental, surrounding community, or other benefits were quantitatively shown (*30*). Because the courts expect that the decisions made and actions taken will be reasonable under the circumstances (*4*), it is vital to have adequate documentation of the decision-making process.

To help implement CSS/CSD, the WSDOT Community Partnership Forum developed a best practices guidebook, *Building Projects That Build Communities* (*31*). This document focuses on effective community-based designs and collaborative decision making. It emphasizes that the key to CSS/CSD is to strive for balance among competing objectives. As such, projects must be supported by sound engineering practices and at the same time incorporate the needs of the jurisdictions involved. On the one hand, there is a need to respect the role of design standards in the development of a project. On the other hand, there is a need to balance application of these standards with other project elements, which may require deviations from the WSDOT guidebook.

WSDOT discovered that as more experience is gained in community partnership projects that utilize CSS/CSD principles, it has become clear that design engineers on these projects must operate with more flexibility than they have in the past. Professional judgment to weigh the trade-offs inherent in urban planning and design is a critical skill. Furthermore, designers must be able to apply a "reasonableness" standard to ensure that safety, mobility, and local community goals are met (*32*).

CSS/CSD implementation means that transportation, community, and environmental goals are all on an equal footing. It is possible that transportation goals and traditional engineering approaches may not be the primary driver for all of the final project decisions (*32*). Idaho's Context-Sensitive Solutions Guide (*33*), for instance, identifies four vision principles associated with CSS/CSD (Figure 4) that emphasize aspects of the CSS/CSD approach.

FIGURE 4 Context-sensitive solutions vision principles.
Source: Context Sensitive Solutions Guide (33).

The nature of CSS/CSD design is balancing the desired design elements of the roadway to achieve the most effective design. For example, in situations with constrained ROWs, design elements must be prioritized to ensure that elements that best help the design meet the stated purpose and need of the project are incorporated. Lower priority design elements that do not support the purpose and need may then be adjusted or eliminated.

NCHRP Report 642: Quantifying the Benefits of Context Sensitive Solutions (*34*) documents the findings of recent research work completed to establish a procedure for identifying and measuring the benefits of applying CSS/CSD principles. The study identified benefits that are strongly related to each CSS/CSD principle (see Table 1). The relationship between the benefit and CSS/CSD principle was determined to be fundamental, primary, secondary, or tertiary. The document then lays out a methodology that clearly demonstrates the metrics to be used to measure the benefits from CSS/CSD projects. This methodology can be used to assess the effectiveness of CSS/CSD implementation for a specific project or program, or to develop lessons learned to improve actions and outcomes on future projects.

Context-Based Design

Context-based design is closely related to CSS/CSD. However, context-based design implies that the street or road is designed to be fully compatible with its context. In contrast, CSS/CSD takes context into account but does not necessarily consider it a governing factor in the design. Garrick

TABLE 1
CSS/CSD PRINCIPLES AND ASSOCIATED BENEFITS

Principles: 1. Use of interdisciplinary teams; 2. Involve stakeholders; 3. Seek broad-based public involvement; 4. Use full range of communication strategies; 5. Achieve consensus on purpose and need; 6. Address alternatives and all modes; 7. Consider a safe facility for users & community; 8. Maintain environmental harmony; 9. Address community & social issues; 10. Address aesthetic treatments & enhancements; 11. Utilize full range of design choices; 12. Document project decisions; 13. Track and meet all commitments; 14. Use agency resources effectively; 15. Create a lasting value for the community

Legend: F = Fundamental; P = Primary; S = Secondary; T = Tertiary

Benefits	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Improved predictability of project delivery	S	S	P	T	P	T	T	T	S	S	T	S	S	S	T
2. Improved project scoping and budgeting	P	S	S	S	S	S	S	S	S	S	T	T	T	P	S
3. Improved long term decisions and investments	S	T	S	T	P	P	S	S	S	S	S	S	T	P	P
4. Improved environmental stewardship	S	S	S	T	T	T	T	F	S	S	T	T	S	S	S
5. Optimized maintenance and operations	P	T	T	T	T	T	T	T	T	S	S	T	T	S	S
6. Increased risk management and liability protection	S	S	T	T	S	S	P	S	S	T	S	P	P	T	T
7. Improved stakeholder/public feedback	T	P	S	P	T	T	T	T	S	T	T	T	T	T	T
8. Increased stakeholder/public participation, ownership, and trust	S	F	S	F	F	P	S	S	P	P	S	F	F	S	P
9. Decreased costs for overall project delivery	S	T	T	T	S	S	T	T	T	T	S	S	S	F	T
10. Decreased time for overall project delivery	P	S	S	T	S	T	T	T	S	T	T	S	S	P	T
11. Increased partnering opportunities	S	P	S	S	T	S	T	T	S	S	T	T	T	S	T
12. Minimized overall impact to human and natural environment	P	S	S	S	S	T	S	T	P	T	P	T	S	T	S
13. Improved mobility for users	S	S	S	T	P	F	S	T	S	T	S	T	S	T	S
14. Improved walkability and bikeability	S	S	S	T	T	P	P	T	S	T	S	T	S	T	S
15. Improved safety (vehicles, pedestrians, and bikes)	S	S	S	T	S	S	F	T	S	T	S	T	S	T	S
16. Improved multi-modal options (including transit)	S	S	S	T	S	P	S	T	S	T	P	T	S	T	S
17. Improved community satisfaction	S	S	F	S	P	S	S	S	F	F	S	P	P	T	P
18. Improved quality of life for community	S	S	T	T	S	S	P	P	P	P	S	T	T	S	F
19. Improved speed management	T	T	T	T	T	S	P	T	S	T	P	T	T	T	S
20. Design features appropriate to context	F	S	S	T	S	S	S	P	P	P	F	T	T	T	S
21. Minimized construction-related disruption	T	P	S	S	T	T	S	S	S	T	T	T	S	T	T
22. Improved opportunities for economic development	S	P	S	S	T	S	T	T	S	S	T	T	T	S	T

Source: NCHRP Report 642: Quantifying the Benefits of Context Sensitive Solutions (34).

and Wang (*35*) outlined basic process for context-based design (Figure 5) to produce good highway design solutions. Although this is an oversimplification of a complex design process, it provides a framework for understanding how decisions regarding design controls and criteria affect the trade-offs that are made. This process attempts to tie together both the urban (or place) function and the mobility function of streets and highways and take into account the full context for the design, including multimodal accommodation and full integration into the surrounding context.

- *Step 1: Define the context.* Context refers not only to the transportation issues but also to the project's social, physical, fiscal, ecological, and political background. Understanding the transportation context includes looking at all the modes of travel that exist in the area and understanding how the facility will fit into the full transportation network, not just the highway network. The importance of a network solution rather than a road-by-road solution needs particular emphasis, as this aspect of design has been neglected over the years. It is also the stage that the needs of the local communities must be assessed.
- *Step 2: Characterize the function.* It is important to explicitly consider all the various functions that the given street or road might serve and to design to accommodate these functions. These functions must explicitly include both transportation (for pedestrians, cyclists, private vehicles, and transit) and nontransportation functions (for entertainment, retail, public gathering, and recreation).
- *Step 3: Select the road typology.* The four most important factors governing the typology of the road are its physical components, the arrangement of these components, definition of the network, and the desired speed.
- *Step 4: Determine the design details.* These details include both engineering and aesthetic factors that contribute to the proper performance of the roadway, such as the alignment design; the cross-section design; the choice and placement of trees and street furniture; and the relationship of the road to the surrounding buildings, land use, or natural environment (*35*).

Needed Data and Input

FHWA describes the Purpose & Need (P&N) statement as the foundation of the decision-making process, influencing the rest of the project development process, including the range of alternatives studied and, ultimately, the alternative selected (*36*). The generally accepted characteristics of an effective P&N statement are as follows:

- The statement is concise, easy to read, and readily understandable.
- It focuses on essential needs for the project, which generally relate to physical condition, operational performance, safety, and access.

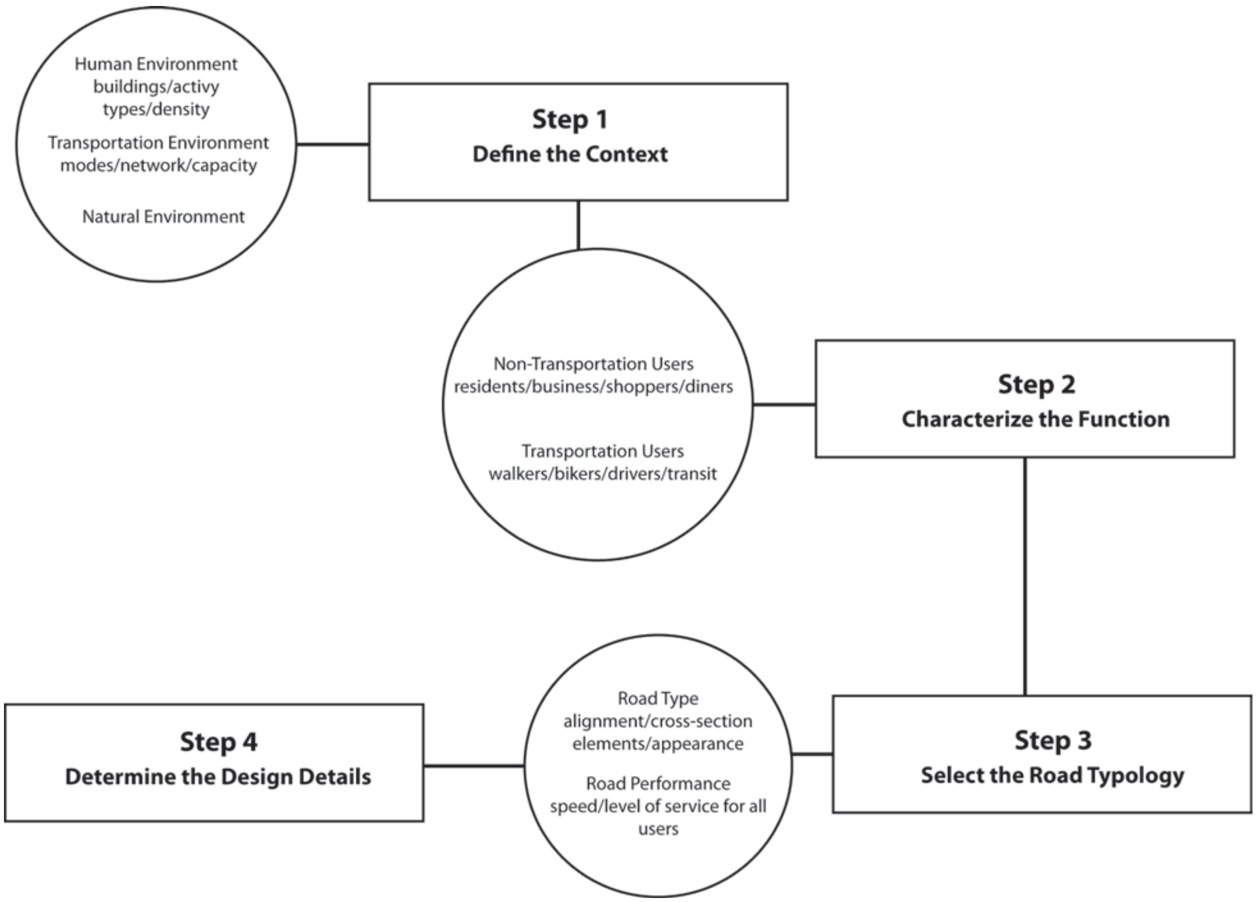


FIGURE 5 Four-step model of highway design process. *Source:* Garrick and Wang *(35)*.

- It delineates other desirable elements (environmental protection, scenic improvements) as separate from the purpose and need.
- It is supported by data that justify the need.
- It focuses on the problems that need to be addressed and for which the proposed project is being considered and is not written in a way that focuses on the solution or too narrowly constrains the range of alternatives.

The issues defined in the P&N document specifically identify what the proposed project is going to address. It is important that the P&N document reflect a full range of public values identified through scoping and public involvement, including community issues and constraints, sensitive environmental resources, and appropriate consideration of other factors. The P&N should be based on input from all interested parties, including STA and regulatory agency staff, consultants, and citizens. Any trade-offs associated with a project must meet the needs identified in the P&N, and measures of effectiveness (MOEs) must be developed with this end in mind.

A collaborative effort between the Pennsylvania and New Jersey departments of transportation (DOTs) has produced *Smart Transportation Guidebook: Planning and Designing Highways and Streets that Support Sustainable and Livable Communities* (*37*). This guidance identifies techniques that can be used to achieve a solid understanding of a given project (Table 2). The techniques range from simple approaches that could be used with projects such as routine maintenance and system preservation to complex approaches for use on more significant projects.

Treatment of Basic Design Controls

Flexibility in the application of design criteria requires a fundamental understanding of the basis for these criteria (i.e., basic design controls) and the impacts of changing the dimensions of a criteria or adding/eliminating design elements. It is critical that trade-offs associated with these decisions be fully understood to preserve the integrity of the resultant design. AASHTO emphasizes this requirement in *A Guide for Achieving Flexibility in Highway Design* by stating that “Only by understanding the actual functional basis of the criteria and design values can designers and transportation agencies recognize where, to what extent and under what conditions a design value outside the typical range can be accepted as reasonably safe and appropriate for the site-specific context” (*38*).

Traditional basic design controls for roadway design projects—design speed, functional classification, and context

TABLE 2
CSS/CSD PRINCIPLES AND ASSOCIATED BENEFITS

Benefits \ Principles	1. Use of interdisciplinary teams	2. Involve stakeholders	3. Seek broad-based public involvement	4. Use full range of communication strategies	5. Achieve consensus on purpose and need	6. Address alternatives and all modes	7. Consider a safe facility for users & community	8. Maintain environmental harmony	9. Address community & social issues	10. Address aesthetic treatments & enhancements	11. Utilize full range of design choices	12. Document project decisions	13. Track and meet all commitments	14 Use agency resources effectively	15. Create a lasting value for the community
1. Improved predictability of project delivery	Secondary	Secondary	Primary	Tertiary	Primary	Tertiary	Tertiary	Tertiary	Secondary	Secondary	Tertiary	Secondary	Secondary	Secondary	Tertiary
2. Improved project scoping and budgeting	Primary	Secondary	Secondary	Secondary	Secondary	Secondary	Secondary	Secondary	Secondary	Secondary	Tertiary	Tertiary	Tertiary	Primary	Secondary
3. Improved long term decisions and investments	Secondary	Tertiary	Secondary	Tertiary	Primary	Primary	Secondary	Secondary	Secondary	Secondary	Secondary	Secondary	Tertiary	Primary	Primary
4. Improved environmental stewardship	Secondary	Secondary	Secondary	Tertiary	Tertiary	Tertiary	Tertiary	Fundamental	Secondary	Secondary	Tertiary	Tertiary	Secondary	Secondary	Secondary
5. Optimized maintenance and operations	Primary	Tertiary	Tertiary	Tertiary	Tertiary	Tertiary	Tertiary	Tertiary	Tertiary	Secondary	Secondary	Tertiary	Tertiary	Secondary	Secondary
6. Increased risk management and liability protection	Secondary	Secondary	Tertiary	Tertiary	Secondary	Secondary	Primary	Secondary	Secondary	Tertiary	Secondary	Primary	Primary	Tertiary	Tertiary
7. Improved stakeholder/public feedback	Tertiary	Primary	Secondary	Primary	Tertiary	Tertiary	Tertiary	Tertiary	Secondary	Tertiary	Tertiary	Tertiary	Tertiary	Tertiary	Tertiary
8. Increased stakeholder/public participation, ownership, and trust	Secondary	Fundamental	Secondary	Fundamental	Fundamental	Primary	Secondary	Secondary	Primary	Primary	Secondary	Fundamental	Fundamental	Secondary	Primary
9. Decreased costs for overall project delivery	Secondary	Tertiary	Tertiary	Tertiary	Secondary	Secondary	Tertiary	Tertiary	Tertiary	Tertiary	Secondary	Secondary	Secondary	Fundamental	Tertiary
10. Decreased time for overall project delivery	Primary	Secondary	Secondary	Tertiary	Secondary	Tertiary	Tertiary	Tertiary	Secondary	Tertiary	Tertiary	Secondary	Secondary	Primary	Tertiary
11. Increased partnering opportunities	Secondary	Primary	Secondary	Secondary	Tertiary	Secondary	Tertiary	Tertiary	Secondary	Secondary	Tertiary	Tertiary	Tertiary	Secondary	Tertiary
12. Minimized overall impact to human and natural environment	Primary	Secondary	Secondary	Secondary	Secondary	Tertiary	Secondary	Tertiary	Primary	Tertiary	Primary	Tertiary	Secondary	Tertiary	Secondary
13. Improved mobility for users	Secondary	Secondary	Secondary	Tertiary	Primary	Fundamental	Secondary	Tertiary	Secondary	Tertiary	Secondary	Tertiary	Secondary	Tertiary	Secondary
14. Improved walkability and bikeability	Secondary	Secondary	Secondary	Tertiary	Tertiary	Primary	Primary	Tertiary	Secondary	Tertiary	Secondary	Tertiary	Secondary	Tertiary	Secondary
15. Improved safety (vehicles, pedestrians, and bikes)	Secondary	Secondary	Secondary	Tertiary	Secondary	Secondary	Fundamental	Tertiary	Secondary	Tertiary	Secondary	Tertiary	Secondary	Tertiary	Secondary
16. Improved multi-modal options (including transit)	Secondary	Secondary	Secondary	Tertiary	Secondary	Primary	Secondary	Tertiary	Secondary	Tertiary	Primary	Tertiary	Secondary	Tertiary	Secondary
17. Improved community satisfaction	Secondary	Secondary	Fundamental	Secondary	Primary	Secondary	Secondary	Secondary	Fundamental	Fundamental	Secondary	Primary	Primary	Tertiary	Primary
18. Improved quality of life for community	Secondary	Secondary	Tertiary	Tertiary	Secondary	Secondary	Primary	Primary	Primary	Primary	Secondary	Tertiary	Tertiary	Secondary	Fundamental
19. Improved speed management	Tertiary	Tertiary	Tertiary	Tertiary	Tertiary	Secondary	Primary	Tertiary	Secondary	Tertiary	Primary	Tertiary	Tertiary	Tertiary	Secondary
20. Design features appropriate to context	Fundamental	Secondary	Secondary	Tertiary	Secondary	Secondary	Secondary	Primary	Primary	Primary	Fundamental	Tertiary	Tertiary	Tertiary	Secondary
21. Minimized construction-related disruption	Tertiary	Primary	Secondary	Secondary	Tertiary	Tertiary	Secondary	Secondary	Secondary	Tertiary	Tertiary	Tertiary	Secondary	Tertiary	Tertiary
22. Improved opportunities for economic development	Secondary	Primary	Secondary	Secondary	Tertiary	Secondary	Tertiary	Tertiary	Secondary	Secondary	Tertiary	Tertiary	Tertiary	Secondary	Tertiary

Fundamental; Primary; Secondary; Tertiary

Source: NCHRP Report 642: Quantifying the Benefits of Context Sensitive Solutions (34).

(urban or rural)—are viewed by some as potentially limiting. For example, the flexibility available to a highway designer is considerably limited once a particular functional classification has been established. Once the functional classification of a particular roadway has been established, so has the allowable range of design speed and often the required level of service. Although the functional classification system establishes a hierarchy for street networks, it remains silent on the size and scale of the various roadways in each classification by leaving that decision to a capacity-based needs calculation. The result is an emphasis on roadway capacity in transportation decision making, which may conflict with community objectives other than accommodating motor vehicle traffic (*39*).

To address this limitation, *Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities* (*40*) identifies multiple arterial and collector thoroughfare types. The guidance presents general design parameters under varying contextual conditions for arterials (see Table 3) and collectors. It provides a range of recommended dimensions and practices for key design criteria. This increased focus on context provides greater flexibility in the approach to other design variables.

With functional class defined, the principal limiting design parameters associated with horizontal and vertical alignment are also by default defined. In addition, the functional classification essentially establishes the basic roadway cross section in terms of lane width, shoulder width, type and width of median area, and other major design features (*18*). The outcome of this mobility-focused process influences the rest of the design process, from working with stakeholders to the final design. A predetermined outcome can be a source of conflict with stakeholders that delays or even stops projects because the thoroughfare design may not be considered compatible with the surroundings or does not address the critical concerns of the community (*40*). A European Commission study of road design in nine European countries identified similar problems associated with the use of functional classification in most of the countries studied. It notes that the conventional classification in most of these countries is really "roadway classification" and not "functional classification," suggesting that functional classification should take into account all the functions of the thoroughfare and not only its vehicle-moving (or road) function (*41*).

In addition to functional classification, speed, and context, the *Green Book* presents the following basic design controls and criteria for its recommended design guidance:

- Design vehicle
- Vehicle performance (acceleration and deceleration)

TABLE 3
GENERAL PARAMETERS FOR ARTERIAL THOROUGHFARES

	Suburban (C-3)				General Urban (C-4)				Urban Center/Core (C-5/6)			
	Residential		Commercial		Residential		Commercial		Residential		Commercial	
Context	Boulevard	Avenue	Boulevard	Avenue	Boulevard	Avenue	Boulevard	Avenue	Boulevard	Avenue	Boulevard	Avenue
Building Orientation (entrance orientation)	front, side	front, side	front, side	front, side	front	front	front	front	front	front	front	front
Maximum Setback [1]	20 ft.	20 ft.	5 ft.	5 ft.	15 ft.	15 ft.	0 ft.	0 ft.	10 ft.	10 ft.	0 ft.	0 ft.
Off-Street Parking Access/Location	rear, side	rear, side	rear, side	rear, side	rear, side	rear, side	rear, side	rear, side	rear	rear	rear	rear
Roadside												
Recommended Roadside Width [2]	14.5 ft.	12.5 ft.	16 ft.	15 ft.	16.5 ft.	12.5 ft.	19 ft.	16 ft.	21.5 ft.	19.5 ft.	21.5 ft.	19.5 ft.
Pedestrian Buffers (planting strip exclusive of travel way width) [2]	8 ft. planting strip	6-8 ft. planting strip	7 ft. tree well	6 ft. tree well	8 ft. planting strip	6-8 ft. planting strip	7 ft. tree well	6 ft. tree well	7 ft. tree well	6 ft. tree well	7 ft. tree well	6 ft. tree well
Street Lighting	For all arterial thoroughfares in all context zones, intersection safety lighting, basic street lighting and pedestrian-scaled lighting is recommended. See Chapter 8 (Roadside Design Guidelines) and Chapter 10 (Intersection Design Guidelines).											
Traveled Way												
Target Speed (mph)	35	25-30	35	35	35	25-30	35	25-30 [3]	35	25-30	30	25-30 [3]
Design Speed	Design speed should be a maximum of 5 mph over the operating speed. Design speed is used as a control for certain geometric design elements including sight distance and horizontal and vertical curvature.											
Number of Through Lanes [4]	4-6	2-4	4-6	2-4	4-6	2-4	4-6	2-4	4-6	2-4	4-6	2-4
Lane Width [5]	10-11 ft.	10-11 ft.	10-12 ft.	10-11 ft.	10-11 ft.	10-11 ft.	10-12 ft.	10-11 ft.	10-11 ft.	10-11 ft.	10-11 ft.	10-11 ft.
Parallel On-Street Parking Width [6]	7 ft.	7 ft.	8 ft.	8 ft.	7 ft.	7 ft.	8 ft.	8 ft.	7 ft.	7 ft.	8 ft.	8 ft.
Min. Combined Parking/Bike Lane Width	13 ft.	13 ft.	13 ft.	13 ft.	13 ft.	13 ft.	13 ft.	13 ft.	13 ft.	13 ft.	13 ft.	13 ft.
Horizontal Radius (per AASHTO) [7]	762 ft.	510 ft.	762 ft.	762 ft.	762 ft.	510 ft.	762 ft.	510 ft.	762 ft.	510 ft.	510 ft.	510 ft.
Vertical Alignment	Use AASHTO minimums as a target, but consider combinations of horizontal and vertical per AASHTO Green Book.											
Medians (which will accommodate single left-turn lanes at intersections) [8]	14-16 ft.	Optional 14 ft.	14-16 ft.	Optional 14 ft.	14-16 ft.	Optional 14 ft.	14-16 ft.	Optional 14 ft.	14-16 ft.	Optional 14 ft.	14-16 ft.	Optional 14 ft.
Bike Lanes (min./preferred width)	5 ft./6 ft.	5 ft./6 ft.	5 ft./6 ft.	5 ft./6 ft.	5 ft./6 ft.	5 ft./6 ft.	5 ft./6 ft.	5 ft./6 ft.	5 ft./6 ft.	5 ft./6 ft.	5 ft./6 ft.	5 ft./6 ft.
Access Management [9]	Moderate	Low	High	Moderate	Moderate	Low	High	Low	Moderate	Low	High	Low
Typical Traffic Volume Range (vpd)	20,000-35,000	15,000-25,000	20,000-50,000	10,000-35,000	10,000-30,000	10,000-20,000	15,000-40,000	5,000-30,000	15,000-30,000	10,000-20,000	15,000-40,000	5,000-30,000
Intersections												
Roundabout	Consider urban single-lane roundabouts at intersections on arterial avenues with less than 20,000 entering vehicles per day, and urban double-lane roundabouts at intersections on Boulevards and Avenues with less than 40,000 entering vehicles per day.											
Curb Return Radii	Refer to Chapter 10 (Intersection Design Guidelines) for details											

Table Notes:

[1] For all context zones with predominantly commercial frontage, this table shows the maximum setback for buildings with ground floor retail. In suburban contexts, office buildings are typically set back 5 ft. further than retail buildings to provide a privacy buffer. In general urban and urban center/core areas, office buildings are set back 0-5 ft. Setback exceptions may be granted for important buildings or unique designs.

[2] Roadside width includes edge, furnishing/planting strip, clear travel way and frontage zones. Refer to Chapter 8 (Roadside Design Guidelines) for detailed description of sidewalk zones and widths in different context zones and on different thoroughfare types. Dimensions in this table reflect widths in unconstrained conditions. In constrained conditions roadside width can be reduced to 12 ft. in commercial areas and 9 ft. in residential areas (see Chapter 5 on designing within constrained rights-of-way).

[3] Desired operating speeds on collector avenues serving C-4 and C-5/6 commercial main streets with high pedestrian activity should be 25 mph.

[4] Six lane facilities are generally undesirable for residential streets because of concerns related to neighborhood livability (i.e., noise, speeds, traffic volume) and perceptions as a barrier to crossing. Consider a maximum of four lanes within residential neighborhoods.

[5] Lane width (turning, through and curb) can vary. Most thoroughfare types can effectively operate with 10-11 ft. wide lanes, with 12 ft. lanes desirable on higher speed transit and freight facilities. Chapter 9 (Traveled Way Design Guidelines) (lane width section) identifies the considerations used in selecting lane widths.

[6] An 8 ft. wide parking lane is recommended in any commercial area with a high turnover of parking.

[7] For guidance on horizontal radius - see AASHTO's section on "Minimum Radii for Low Speed Urban Streets - Sharpest Curve Without Superelevation." Dimensions shown above are for noted design speeds and are found in Exhibits 3-16 (Page 151) in *A Policy on Geometric Design of Highways and Streets* (2004), assuming a superelevation of -2.0 reflecting typical cross slope.

[8] These median widths can accommodate a single-left turn lane at intersections. The boulevard median width (16 ft.) can accommodate a minimum 6-foot wide pedestrian refuge adjacent to the turn lane. In constrained conditions, raised medians on arterial thoroughfares can be reduced to a minimum of 10 ft. and accommodate a single left-turn lane.

[9] Access management involves providing (in other words, managing) access to land development in such a way as to preserve safety and reasonable traffic flow on public streets. Low, moderate and high designations are used for the level of access restrictions. A high level of access management uses medians to restrict mid-block turns, consolidates driveways and controls the spacing of intersections. A low level of access management limits full access at some intersections.

Source: Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities (40).

- Driver performance (age, reaction time, driving task, guidance, etc.)
- Traffic characteristics (volume and composition)
- Capacity and vehicular level of service
- Access control and management
- Pedestrians and bicyclists
- Safety

However, the following four design controls are used differently in the application of CSS/CSD principles than in the conventional design process:

- Design speed
- Location
- Design vehicle
- Functional classification

In conventional design practice, design speed has been encouraged to be as high as practical—the designer begins with the highest value and then works down through the range. In CSS/CSD practice, the designer begins by considering contextual factors, resulting in design speed typically taking on a greater range. This requires an understanding of the trade-offs associated with the selected design speed—the functional classification, roadway type and context, and surrounding land use characteristics (e.g., predominantly residential or commercial). In urban areas, higher design speed is not a prerequisite for higher capacity, as under interrupted flow conditions intersection operations and delay have a much greater impact on capacity than does design speed. Once selected, design speed then becomes the primary control for determining the following design values:

- Minimum intersection sight distance
- Minimum sight distance on horizontal and vertical curves
- Horizontal and vertical curvature

Like design speed, location also takes into consideration the context and surrounding land use characteristics. This includes the level of activity and location of pedestrians, bicyclists, and transit, as well as the types and intensity of surrounding land uses.

The design vehicle selected directly influences the selection of design criteria for lane width and curb return radii. Under conventional design, often the designer will select the largest design vehicle (e.g., WB 50 or WB 65) that could use the roadway, regardless of the frequency of use by that vehicle. However, it is not always practical or desirable to choose the largest design vehicle that might use the facility because the effects on pedestrian crossing distances, speed of turning vehicles, and the like may be inconsistent with the community vision and goals. CSS/CSD emphasizes an analytical approach in the selection of design vehicle, including evaluation of the trade-offs involved in selecting one design vehicle over another. Using this approach, after the evaluation of trade-offs, the designer selects the largest vehicle that will use the facility with considerable frequency as a design vehicle. The designer further selects a control vehicle, which is a vehicle that will use the facility infrequently but must be accommodated. It is permissible for the control vehicle to encroach onto opposing lanes or the roadside or be forced to make multipoint turns.

When Massachusetts created its new *Project Development and Design Guide* (*42*), it identified a broader range of basic design controls that better respond to the context of Massachusetts communities and to the purpose and need of typical road and bridge projects in the commonwealth in the 21st century (*43*). These include roadway context, roadway users, transportation demand, MOEs, speed, and sight distance. For example, the new design controls include expanded ranges of design speed, with lower acceptable values for all types of roadways. This approach of utilizing increased and more flexible design controls allows for greater variation in potential solutions and a corresponding greater need for adequate evaluation of the trade-offs associated with each alternative design. Table 4 compares the guidance in the 1997 and 2006 manuals.

TABLE 4

COMPARISON OF DESIGN SPEED RANGES BETWEEN THE 1997 AND 2006 DESIGN GUIDES

Roadway Type (Based on 1977)	1997 Manual	2006 Guidebook
Rural Arterial (Level Terrain)	60 to 75 mph	40 to 60 mph
Urban Arterial	30 to 60 mph	25 to 50 mph
Rural Collector (Level Terrain)	60 mph	30 to 60 mph
Urban Collector	30 mph (minimum)	25 to 40 mph

Sources: Project Development and Design Guide (42) and *Highway Design Manual (44).*

WSDOT's *Understanding Flexibility in Transportation Design—Washington* (*45*) outlines the potential impacts that can result when the feature listed is changed in the manner indicated and all other features are held constant (Table 5). This type of guidance is extremely helpful in understanding the trade-offs associated with changes to basic design elements.

TABLE 5

POTENTIAL IMPACTS FROM CHANGES IN DESIGN PARAMETERS

Feature	Change	Potential Impacts
Design Speed	Increase	• Shorter travel times (depends on LOS) • Reduced opportunity to view features and services adjacent to roadway • Decrease in safety
	Decrease	• Increased opportunity to view features and services adjacent to roadway • Improved pedestrian/bicyclist environment • Increase in safety
Lane Width	Increase	• Additional room for vehicles to maneuver • Higher operating speeds • Increased impervious surface • Increased capacity • Longer pedestrian crossing distances—greater risk • Can provide room for turning movements at intersections • Can provide room for additional lanes • More room for bicyclists
	Decrease	• Reduced room for vehicles to maneuver • Reduced capacity • Reduced vehicle speeds • Shorter pedestrian crossing distances • Decrease in safety for pedestrians
Shoulder Width	Increase	• Increased space for errant and disabled vehicles • Increased space for bicycles • Increased impervious surface • Increased impervious area to be mitigated • Longer pedestrian crossing distances
	Decrease	• Reduced area for errant or disabled vehicles • Reduced area for bicycles and pedestrians • Reduced impervious area to be mitigated • Shorter pedestrian crossing distances

Source: Milton and St. Martin *(45).*

Alternative Analysis

The goal of an alternatives evaluation is to provide an objective and balanced assessment of impacts, trade-offs, and benefits of each alternative. This requires careful selection of, and stakeholder agreement on, MOEs to be used as evaluation criteria. The MOEs need to reflect community and environmental objectives as well as transportation.

Process

In *Smart Transportation Guidebook: Planning and Designing Highways and Streets that Support Sustainable and Livable Communities* (37), the Pennsylvania and New Jersey DOTs have outlined a process to assess a full range of alternatives. In this process, MOEs are "balanced" against one another to determine the best solution to meet project purpose and need. This process also portrays the trade-offs between measures, such as a reduced traffic level of service balanced against a corresponding increase in civic value associated with on-street parking. The guidance recommends that following process steps:

- *Summarize the assessment* – Collapse the assessment to simple and appealing summary products such as charts, tables, matrixes, and spreadsheets. Illustrations (photographs, sketches, or abstract computer graphics) could be used for those measures best described graphically.
- *Understand important trade-offs* – Illustrate the balance ("trade-off") between important competing measures. One criterion might offset another, such as pairing vehicular traffic service and pedestrian level of service. Successful designs address these trade-offs and achieve a balance of values that can gain community consensus.
  - Most important measures needing to be balanced are usually "apples and oranges" and are impossible to collapse to a single common measure. Although disparate measures cannot be directly compared in common terms, simply computing and comparing them represents an improvement. The "apples and oranges" dilemma is not a fault of the process, but more likely an indication that a meaningful set of evaluation measures has been included.
- *Avoid weighting and scoring schemes* – These schemes are likely to be cumbersome and contentious. At this nearly final stage in the planning process, participants' energy is far better directed toward arriving at a solution that addresses the wide range of project needs and objectives, rather than creating numerical weighting schemes for disparate measures of success that do not lend themselves to such treatment.
- *Collaborate, do not vote, on a recommended solution* – Avoid putting the decision on a recommended solution to a vote, regardless of how representative the study group is of broad community viewpoints. Rather, informed consent or negotiated recommendation could be reached through a collaborative process. At this point, a third-party facilitator, skilled in consensus building, may be a valuable input (*37*).

The Massachusetts Department of Transportation's (MassHighway) new *Project Development and Design Guide* suggests that alternatives should be developed to comparable levels and presented in an evaluation matrix (for an example matrix, see Figure 6). The evaluation matrix visually presents the alternatives in a manner that facilitates comparison and helps ensure that the impacts of each alternative are consistently considered when selecting the best option (*42*).

Criteria	No Build	Short-Term Packages 1,2,3	Alternative 2A	Alternative 2B	Alternative 3A	Alternative 3B
Mobility	High	Pos	Pos	Pos	Pos+	Pos
Safety	Mod	Pos	Pos	Pos	Pos	Pos
Wetlands	None	Low	Mod	Mod	Mod	Mod
Aquifers	None	None	None	None	None	None
Protected/ Recreational/ Open Space	Low	Pos	Pos	Pos	Pos	Pos
Hazardous Materials	None	*	*	*	*	*
Noise	Low	Low	Low	Low	Low	Low
Air Quality	Low	Pos*	Pos*	Pos*	Pos*	Pos*
Wildlife Habitat	None	Low	Low	Low	Low	Low
Cultural Resources	None	Low*	*	*	*	*
Right-of-way	None	Low*	Low*	Low*	Low*	Low*
Parking	None	Low*	Low*	Low*	Low*	Low*
Emergency Response	Low	Pos	Pos	Pos	Pos	Pos
Visual Impacts	None	Low	Mod	Mod	Mod	Mod
Costs	None	$2.4M	$60M	$48M	$44M	$58M

FIGURE 6 Route 110 & 113 Methuen Rotary Interchange Study Evaluation Criteria Summary Matrix. *Source: Route 110 & 113 Methuen Rotary Interchange Study (46).*

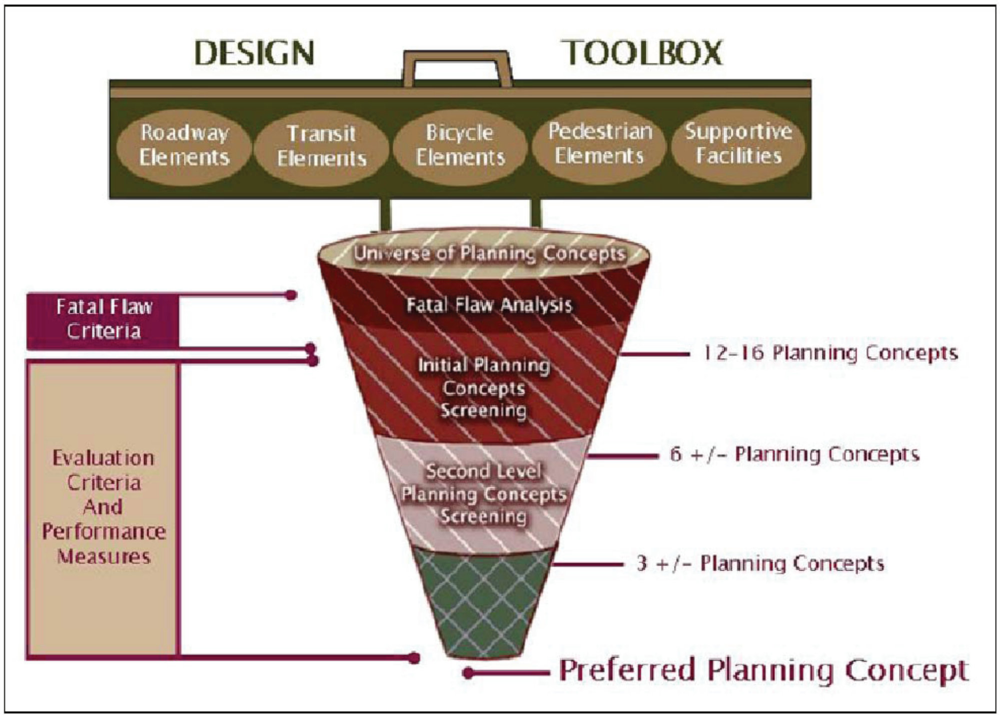


FIGURE 7 Project screening process. *Source: Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities (40).*

The ITE *Context Sensitive Solution in Designing Major Urban Thoroughfares for Walkable Communities* (*40*) outlines the alternative screening process (Figure 7), showing that trade-offs are considered at multiple places in the planning process. This process begins with evaluating fatal flaws and progresses to trade-off evaluation in increasingly greater detail as alternatives are reduced, until finally a preferred concept is selected.

WSDOT had developed *Understanding Flexibility in Transportation Design—Washington* as a companion to WSDOT's *Design Manual*. The guidance was created to present information centering on the rationale for decision making and the trade-offs associated with many elements included in transportation projects in CSS/CSD (46). It outlines how to integrate CSS/CSD principles into all aspects of the project delivery process, and presents case studies of projects within Washington State that illustrate the use of the CSS/CSD approach. The document compiles the issues that are associated with transportation facility design, discusses the trade-off considerations related to each issue, prompts the user to think about how a particular consideration affects other factors related to highway design, and lists resources with each section. It covers several overarching topics, including the following.

- *Legal Liability Issues* – The guidance stresses the importance of full documentation of the options considered, the trade-offs identified, and the rationale behind the decisions made. It provides a historical perspective and outlines current legal responsibility and liability.
- *Consideration of Facility Users* – The guidance points out that the CSS/CSD process will frequently entail making trade-offs in order to provide a safe and functional facility for all users. It discusses many of the trade-offs that need to be considered for pedestrians, bicyclists, transit, and motorized vehicles.
- *Environmental Considerations* – The guidance identifies a variety of environmental, scenic, aesthetic, historic, and natural resource values that might be considered and addressed in the planning, design, and environmental review processes of project development in order to avoid, minimize, or otherwise mitigate project impacts. It covers the environmental issues of urban forestry; urban streams, fish, wildlife, and plant resources; cultural and historic resources; air quality; noise; vibration; night sky darkness; and, use of recycled materials.
- *Design Considerations* – The guidance provides information regarding many of the available design alternatives for roadways and intersections and discusses the trade-offs associated with each alternative. The guidance suggests avoiding the tone of "good" and "bad," and instead centering on the perceived benefits and drawbacks of features depending on the objective of those interested in the project. It covers facility purpose and characteristics, land use transitions, roadway, roadside, intersections, access, ROW management and utilities, parking, traffic calming, illumination, visual functions, streetscape amenities, and stormwater management.
- *Community Involvement and Project Development* – The guidance presents trade-offs based on the needs

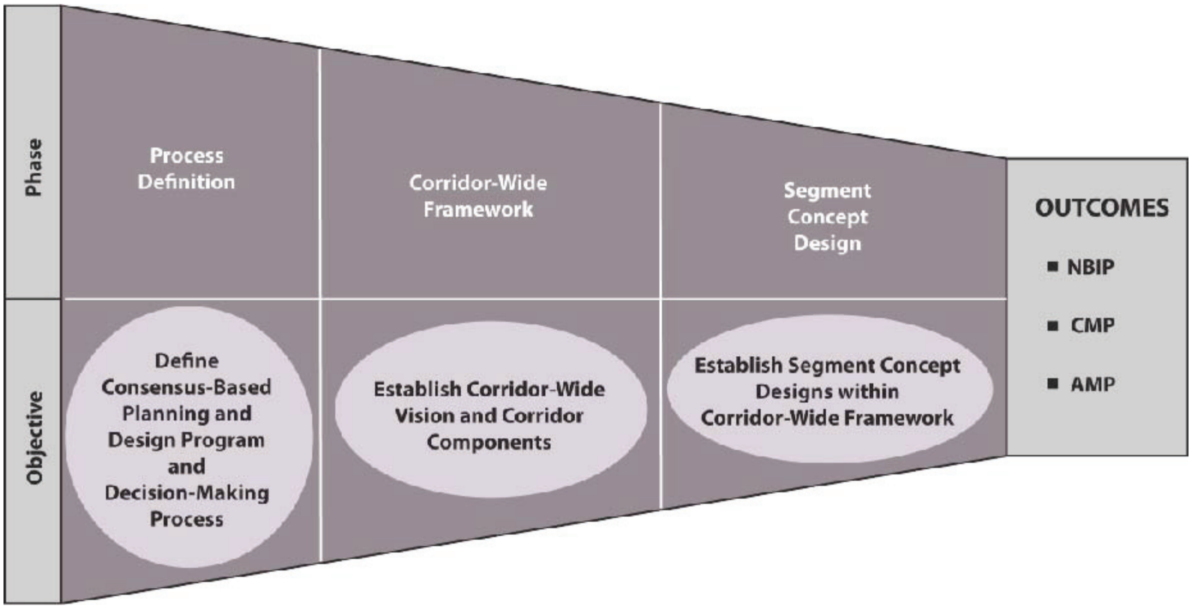


FIGURE 8 Needs-based implementation plan three-phase process. *Source:* Rauch *(48)*.

of safety and mobility associated with highway design, and of livability, natural environment, and aesthetics associated with community character and values. It suggests focusing the analysis to inform all parties of the needs and expectations of the other involved parties and of the benefits and drawbacks to many of the elements frequently included in transportation projects.

- *Long-Term Impacts* – The guidance discusses in detail the trade-offs associated with many design elements and the liability issues that may arise owing to inappropriate designs, and encourages thoughtful consideration of the trade-offs associated with the varied treatments available to the designer (*46*).

The Arizona Department of Transportation has developed a CSS/CSD approach called the needs-based implementation plan (NBIP), which consists of a coordinated, collaborative team effort to assess needs and develop solutions for a corridor. The NBIP process takes a context-sensitive approach by balancing safety, mobility, and the preservation of scenic, aesthetic, historic, environmental, and other community values. Figure 8 shows the three phases of the NBIP process: process definition, corridor-wide framework, and segment concept design. In the process definition phase, the project team defines specific tasks to be completed in the remaining phases. In the corridor-wide framework phase, the project team helps the community arrive at a preferred planning concept for each corridor segment. Finally, the segment concept design phase allows community representatives to help the project team select more detailed design elements for each segment (*47).*

Develop a Full Range of Alternatives

In *Smart Transportation Guidebook: Planning and Designing Highways and Streets that Support Sustainable and Livable Communities (37)*, the Pennsylvania and New Jersey DOTs jointly developed a generalized checklist to help ensure that alternatives are inclusive (Table 6). In addition, the guidance provides checklists to help develop alternatives to address specific issues, including mainline congestion, resurfacing, intersection congestion, bridge deficiency, and intersection safety (Table 7).

A feature of the Arizona NBIP is that citizen stakeholders play an active role in the planning, design, and construction of the corridor. On the State Route 179 corridor in Sedona, Arizona, the team prepared a series of “fishbone” diagrams indicating how community members linked together cross-sectional ideas into segment-level concepts. This visual representation of the potential cross sections of the roadway helped ensure that the full range of alternatives was considered. Figure 9 shows proposed combinations of roadway design elements for one segment of the corridor (*48*).

Often a red flag or fatal flaw analysis of alternatives is performed early in the alternative development process. The idea of this analysis is to examine key areas such as environmental, historic, social, ROW, utility, and engineering (e.g., geometric, geotechnical), and identify locations of concern. Many STAs have developed red flag checklists to aid in this process. Once a location of concern has been identified, it must be determined if the issue is a “fatal flaw.” Fatal flaws are typically associated with significant negative economic, environmental, or historic impacts. Alternatives that have fatal flaws are then removed from further consideration. However, this process must be used judiciously, as the integrity of the process requires that all reasonable alternatives receive a fair assessment.

TABLE 6

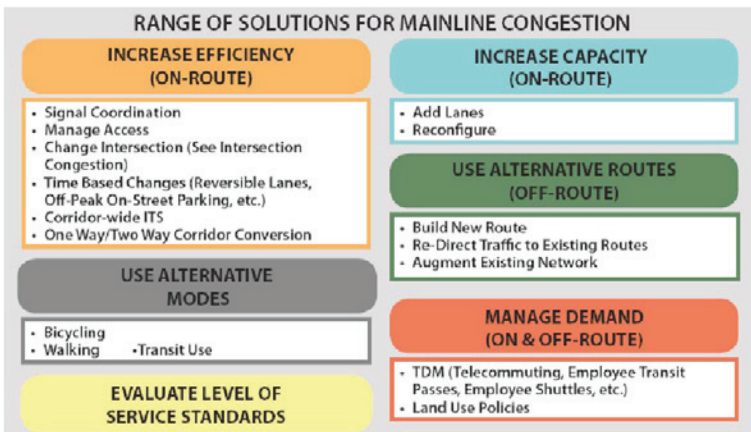
CHECKLIST FOR EXPLORING ALTERNATIVES

Strive For	Avoid
Multi-Party Input – DOT, engineering consultant, specialists (historic, environmental), stakeholder representatives.	Project Staff Only Input – Inside project team, generalists where specialists are needed.
Collaborative – Participants sift through wide range of alternatives, with no exclusions. Alternatives are discussed in structured dialogue sessions.	Prescriptive – Range of alternatives is prescreened and limited. Some alternatives are dismissed early as "fatally flawed."
Iterative – Alternatives are considered again, with the same process as described above, as further understanding and evaluation is gained.	One Time – Alternatives are "closed down" after an early "final screening."
Aware of Value/Price -- Some understanding of value/price relationship at early stage and throughout.	Focusing only on High Price Solutions – Little understanding of value/price during alternatives stage.
Expansive – Process seeks alternatives that yield multiple quality-of-life benefits.	Constrained – Alternatives are limited to narrow range that addresses only one issue or concern.

Source: Smart Transportation Guidebook: Planning and Designing Highways and Streets that Support Sustainable and Livable Communities (37).

TABLE 7

RANGE OF SOLUTIONS FOR MAINLINE CONGESTION



Source: Smart Transportation Guidebook: Planning and Designing Highways and Streets that Support Sustainable and Livable Communities (37).

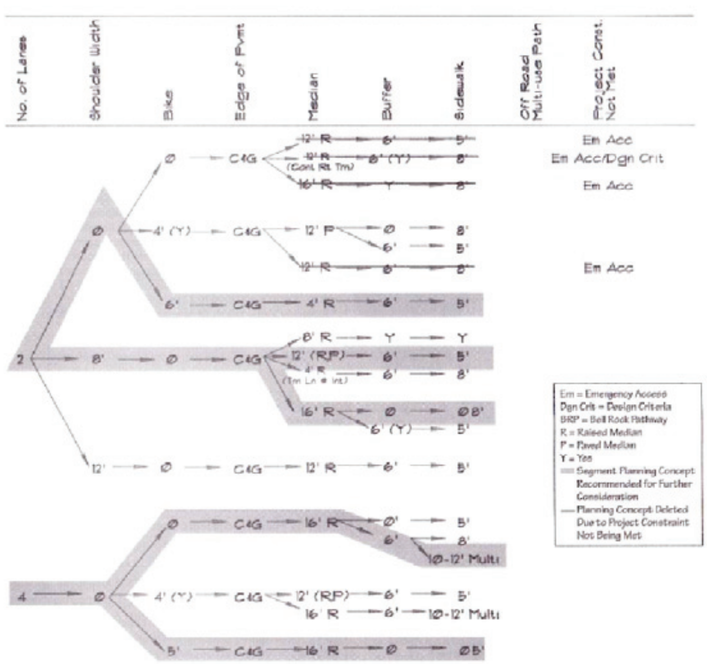


FIGURE 9 Fishbone diagrams of roadway cross-sectional elements. *Source:* Rauch *(48)*.

Measures of Effectiveness

It is important that MOEs be directly related to the stated project needs. These needs often focus on the overarching categories of physical condition, operational performance, safety, access, environment, and social and historical. When possible, the MOEs selected for use in alternative analysis are to be standard, widely accepted measures. For example, when dealing with operational performance, the use of level of service, hours of delay, or total travel time would be appropriate. The key is for chosen MOEs to be transparent and easily conveyed to all stakeholders. Achieving CSS/CSD means generating project outcomes that reflect community values; are sensitive to scenic, aesthetic, historic, and natural resources; and are safe and financially feasible (*49*).

It is critical to identify MOEs early in the process with direct input from stakeholders. Even if only a few measures

TABLE 8

EXAMPLES OF SMART TRANSPORTATION MEASURES OF SUCCESS

Measure of Success	Units	Potential Source
TRAFFIC		
Peak Hour LOS (intersection) **Non-Peak Hour LOS (intersection)**	• Level of Service • Seconds of delay • Queue lengths • Daily Profile	HCS intersection – or SIDRA roundabout runs, existing and design year
Screen line capacity (at *X* segments throughout the corridor)	Peak hour/peak direction vehicles	HCM source flows on planned lane count
Volume/Capacity (at *X* segments throughout the corridor)	Peak hour volume/capacity ratio	• HCM source flows on planned lane count • Traffic Study
Corridor travel times between selected origins and destinations	Minutes	Simulation such as Synchro, VISSIM
Reduction in existing VMT	VMT	Simulation such as Synchro, VISSIM
Desired travel speeds in Area X, Area Y	MPH expected based on roadway design and characteristics	NJDOT/PennDOT Design Manual/ AASHTO Green Book
SAFETY		
Reduction in number of driveways	Number of driveways	Field Count
Reduction in unprotected left turns	Peak hour vehicles	Signalized intersection analysis and existing turning movements
Potential safety improvements at documented high-crash locations	Potential for increasing safety	Crash data and safety audit
Median that meets certain criteria	Linear feet (lf)	Map take-off
Shoulders that meet certain criteria	Linear feet (lf)	Map take-off
ALTERNATIVE MODES		
Sidewalk	lf of new sidewalk	Map take-off or GIS
Restored sidewalk	lf of replaced sidewalk	Map take-off or GIS
Safe pedestrian crossings	Number of well-marked crosswalks,and/or speed and volume of crossing traffic	Map take-off or GIS
Bicycle access	lf of bike lanes, paved shoulders, or wide curb lanes	Map take-off or GIS
Public transportation	Bus stops with safe pedestrian crossings	Map take-off or GIS
Ease of crossing for farm equipment in rural areas	• Crossings • Desired speed based on road design	Map take-off or GIS NJDOT/ PennDOT Design Manual/ AASHTO Green Book

Table 8 continued on p.25

Table 8 continued from p.24

Measure of Success	Units	Potential Source
COMMUNITY CHARACTER		
Rural road-front in purchased farm land, conservation easement	lf, Acres	Map take-off or GIS
Town streetscape	lf	Left turn lane placement and existing turning movements
Historic resources	• Number of NRHP-Eligible Buildings Impacted/Displaced • Number of NRHP-Eligible Districts Impacted	Map take-off or GIS
Businesses	Number Impacted/Displaced	Map take-off or GIS
Residences	Number Impacted/Displaced	Map take-off or GIS
Community facilities	Number Impacted/Displaced	Map take-off or GIS
Land use/growth management	Consistency with local and regional plans and policies	Comprehensive Plans or similar documents
Open space/parklands	Number Impacted/Displaced	Map take-off or GIS
ENVIRONMENTAL		
Wetlands	• Number Impacted • Acreages Impacted • Quality	Map take-off or GIS
Stream crossings	• Number of New Crossings • Acreage of New Crossings	Map take-off or GIS
Floodplains	Acreages Impacted	Map take-off or GIS
COSTS		
Total project costs	Dollars in Year of Expenditure	Estimated
Cost per new trip	Dollars per trip	Estimated cost, new capacity added
Cost per new VMT	Cents per mile	Estimated cost, new VMT capacity added
Cost per user	Dollars per user	Estimated cost, new users

Source: Smart Transportation Guidebook: Planning and Designing Highways and Streets that Support Sustainable and Livable Communities (37).

are finally selected for project evaluation, consideration of a wide range of measures at the beginning of a project can help identify important community values that may otherwise be overlooked. Further, it is critical to develop MOEs before alternatives have been formulated to help prevent stakeholders from attempting to steer the analysis toward certain types of alternative solutions instead of focusing on establishing MOEs to capture what is most important. The *Smart Transportation Guidebook: Planning and Designing Highways and Streets that Support Sustainable and Livable Communities* (*37*) presents a table listing potential MOEs by category (Table 8). Although not all-inclusive, referencing this sort of tool early in the project planning process is vital to ensure that sufficient and appropriate MOEs will be available to address project purpose and need.

Evaluation criteria can be quantitative or qualitative, depending on the complexity of the problem, the expected level of controversy, the structure and scope of the public involvement process, and the preference of decision makers. In general, projects involving difficult trade-offs and high degrees of controversy benefit from the use of quantitative measures. The use of appropriate MOEs and defensible data can help focus stakeholders on outcomes, remove emotional bias from the discussion and provide definitive rationale to support trade-off decisions to help move stakeholders off of strongly held positions. Whether the criteria are qualitative or quantitative, they help to focus the data collection and the discussion on the relative merits of the alternatives in relation to critical issues, and on trade-offs that distinguish among the alternatives under consideration (4).

The MassHighway *Project Development and Design Guide* (*42*) departed from the traditional measure of vehicular Level of Service owing to its limited way of measuring the benefits of a transportation project. To account for this, the guidance provides new basic design controls associated with measures of effectiveness. These MOEs include levels of service for all users (pedestrians, bicyclists and motorists), facility condition, safety, resource preservation, aesthetics, accessibility, environmental justice and other factors. This allows the designer to better assess trade-offs, make more informed decisions, and include project elements in the proposed design that respond to the real needs of the community, beyond the simple (and not always desirable) need to move more cars through an area at faster speeds (*43*). This approach will be reflected in refinements to the *Highway Capacity Manual* for the 2010 update, which will provide procedures for determining multimodal quality of service and level of service.

ITE's *Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities* identifies several MOE categories:

- Mobility: travel demand, roadway capacity, level of service, travel time, connectivity, circulation, access, truck movement, access to multiple travel modes, etc.;
- Social and Economic Effects: socioeconomic and cultural environment (historic, cultural, and archaeological resources; residential and business displacement/dislocation; socioeconomics and equity; neighborhood integrity and cohesion; economic development; place-making qualities);
- Environmental Effects: positive and negative effects of natural environment (air quality, noise, energy consumption, water quality and quantity, vegetation, wildlife, soils, open space, park lands, ecologically significant areas, drainage/flooding aesthetics and visual quality); land use (residential patterns, compatible uses, development suitability according to community values, etc.);
- Cost-effectiveness and Affordability: capital costs, operations and maintenance costs, achievement of benefits commensurate with resource commitment, sufficiency of revenues, etc.; and
- Other Factors: compatibility with local and regional plans and policies, constructability, construction effects, etc. (*40*).

Benefit-Cost Ratio

Most projects offer a range of alternatives with different costs, corresponding to different levels of value. However, the importance of understanding alternatives based on a value-to-price ratio is often overlooked. Current guidance is fairly silent on this subject and does not direct projects toward the most effective value-to-price yield. Performance measures such as cost per existing trip, cost per new trip, and cost per time savings for a representative trip may be used to better understand the return on a proposed investment (*37*).

Figure 10 illustrates this concept. The x-axis represents total project costs such as capital costs; life-cycle costs; environmental, historical, and social impacts; and user costs. The y-axis represents project benefits such as travel time savings, crash reduction, emission reduction, and improved access. Alternatives are examined to see where they fall along the continuum, with the overall goal being to "right-size" a project.

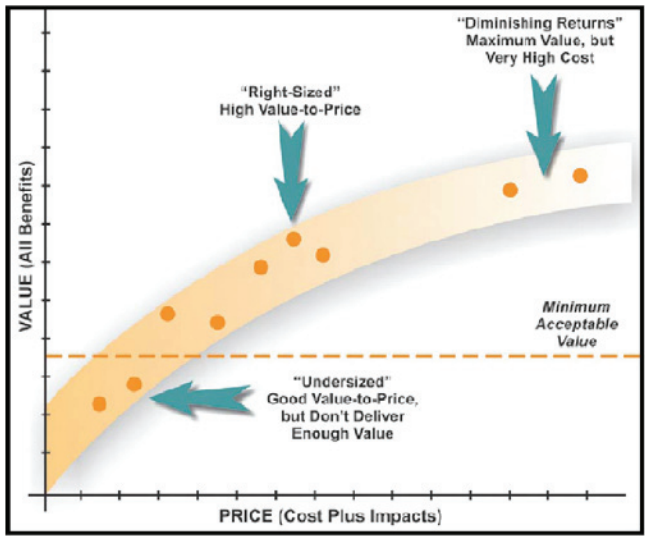


FIGURE 10 Value to price curve. *Source: Smart Transportation Guidebook: Planning and Designing Highways and Streets that Support Sustainable and Livable Communities (37).*

Benefit/cost analysis needs to be used with caution when examining transportation projects. It can be difficult to adequately represent factors such as safety, equity, and economic development in a benefit/cost analysis.

Project Documentation and Decision Process

One of the critical aspects of trade-off decisions is ensuring that the decision is adequately documented and then that the documentation is retained, as both crashes and tort claims may occur many years after the decisions and construction. In such cases, the agency's actions may be defended by professionals who were not directly involved in the actual project execution. It is unfortunately the case that design agencies lose or settle claims not because their staff actions were inappropriate, but because the project files are incomplete or missing key documentation, and staff responsible for the project are no longer available to explain what was done and why (*4*). Putting all aspects of a project in writing is important not only to improve communication among team members and the community, but also to protect against litigation and ease the transition when staff change. Pennsylvania Department of Transportation's (PennDOT's) CSS/

CSD training, for instance, includes a session by the attorney general's office that discusses the need to document the use of sound engineering judgment. Such practices offer more protection than blind adherence to the maximum values in design manuals (*50*).

As important as adequate documentation is the need for a clearly understood decision process. Projects are made up of a series of tasks, each of which may involve a series of trade-off decisions that result in a final project decision. As such, it is critical that the decision process identify what decisions will be made and by whom, and what analyses, processes, and documents will be produced to support the final outcome. A successful process for making trade-off decisions contains several crucial elements.

Develop Decision Process

The purpose of developing a decision process is to identify the problem completely and accurately, select the best alternative, enhance agency credibility, and make efficient use of resources—in short, to make good transportation investment decisions. A decision process incorporates the following elements:

- The decision points in the process
- Who will make each decision
- Who will make recommendations for each decision
- Who will be consulted on each decision
- How recommendations and comments will be transmitted to decision makers.

Decision Points

The CSS/CSD Project Development Process includes a recommended set of decision points. These basic steps will support almost any planning process, but may need to be refined to suit a particular project. The focus of a decision process is often mistakenly placed on only the final decision, overlooking the many intermediate decisions. For example, in an alternative selection process, the alternative development and screening occurs before detailed alternative evaluation. Whether or not it is explicitly stated, the early steps involve decisions on compiling the list of potential alternatives, the manner and level of detail in which they will be outlined or described, the feasibility criteria to be used, and the list of feasible alternatives to be considered further.

Breaking down larger decisions into their component pieces also helps to identify the differences in stakeholder involvement needed at various points in the process. It may be important for different stakeholders to be involved at various decision points, or for different parties to make different decisions. For example, some decisions require specific technical expertise, whereas others require broader participation and perhaps less technically oriented input (*4*).

Case Studies

Several guidance documents, including the following, provide CSS/CSD case studies:

- *Building Projects That Build Communities (31)*
- *Understanding Flexibility in Transportation Design—Washington (45)*
- *CSS National Dialog (51)*
- *Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities (40)*
- *A Guide to Best Practices for Achieving Context-Sensitive Solutions (4)*
- *Context-Sensitive Design Around the Country: Some Examples (27)*
- *Quantifying the Benefits of Context Sensitive Solutions (34)*

The *CSS National Dialog* is a collection of case studies that were submitted to the National Dialog and have been transferred to the CSS clearinghouse database (*51*). This database is searchable by keyword or name of project and can be accessed at www.contextsensitivesolutions.org.

PRACTICAL SOLUTIONS/DESIGN

Practical Solutions and Practical Design (Practical Solutions/Design) refers to a design process that attempts to maximize the rate of return for the individual project while maximizing the rate of return for the complete system. This focus on systemwide optimization is not adequately addressed by CSS/CSD, which focuses primarily on incorporating all relevant factors into the project development process to account for context. Practical Solutions/Design, in contrast, acknowledges that there are finite resources that can be expended on the transportation system as a whole. The intent of the Practical Solutions/Design process is not to optimize the individual project, but rather to allow increased optimization of the entire transportation system with concern for mobility and safety. This approach results in "reasonable" solutions for individual projects while preserving limited funds to address additional problems elsewhere in the system. To achieve this, the following general principles are utilized to control the potential for overdesign of a project:

- *Targeted Goals in a P&N Statement* – The P&N statement identifies specific targets for performance and avoids generalized statements, such as "improve mobility." For example, a specific target could be to shorten intersection delay to less than 50 seconds per vehicle during the typical peak hour.
- *Meeting Anticipated Capacity Needs* – Rather than using a broad level of service goals, more detailed quality of service targets need to be identified.
- *Safety Evaluation Against Existing Conditions* – The safety of each alternative is to be compared as incre-

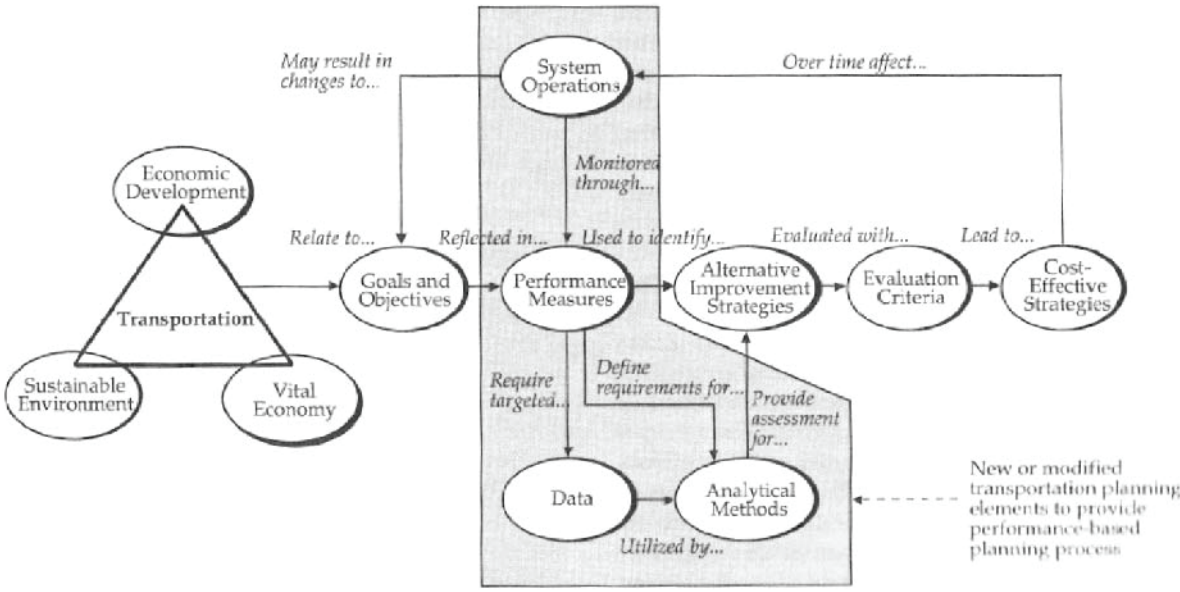


FIGURE 11 Elements of a performance-based planning process. *Source: NCHRP Report 446: A Guidebook for Performance-Based Planning (53).*

mental gains from the existing conditions. Simple selection of the alternative that has been judged to be "safer" misses the opportunity to evaluate the safety gains based on the marginal rate of return.

- *Maximize Rate of Return* – Increased investment yields less than a proportional increase in overall value at the point of diminishing returns (see Figure 10) (*17*).

Performance-Based Planning

Performance-based planning has most often been applied at the organizational level to assess program conformance with a stated overall transportation plan or goals and objectives. However, the process is just as applicable for evaluating trade-offs associated with alternatives, especially when put in the context of CSS/CSD. The use of outcome-based performance measures, as opposed to the traditional use of output-based performance measures, is especially apt. Furthermore, as CSS/CSD becomes the accepted practice for STAs, there is a need to gauge performance in meeting strategic goals and objectives. Figure 11 illustrates a general framework for applying performance-based planning.

Output measures generally reflect the quantity of resources used, the scale or scope of activities performed by an organization, and the efficiency in converting those resources into some type of product. Output measures are most often used as indicators of organizational activity or performance, but stop short of identifying results as viewed by intended beneficiaries. Nonetheless, outcome measures reflect success in meeting stated goals and objectives, which can be drawn from the project P&N statement, and can be augmented with customer satisfaction measures that focus on the beneficiaries of the project. *A Guidebook for Performance-Based Transportation Planning* (*52*), for instance, includes a *Performance Measures Library* as Appendix A. Its purpose is to provide practitioners of performance-based planning with a concise guide to many of the measures in use around the United States today.

Context-sensitive project solutions often appear deceptively simple, yet the holistic, interdisciplinary, community-driven nature of CSS-based project delivery makes measurement challenging. *Performance Measures for Context Sensitive Solutions: A Guidebook for State DOTs* (*53*) presents a framework for organizing performance measures and discusses key focus areas. The guidance assumes that individual agencies will develop their own MOEs tailored their specific needs. It contains four major sections:

- *Guiding Concepts for CSS Performance Measurement Programs.* This section offers DOTs a framework for organizing measures that addresses CSS-related processes and outcomes at the project level and organizationwide, and provides an understanding of some basic principles for measurement of CSS performance.
- *Project-level Focus Areas.* This section describes how agencies can assess performance of individual projects or groups of projects by targeting key focus areas, and gives pointers for potential performance measures in each focus area.
- *Organizationwide Focus Areas.* This section describes focus areas that agencies need to target as they assess overall organizational performance, and gives pointers for potential performance measures in each focus area.
- *Tips for Getting Started.* This section provides suggestions on creating and using a CSS performance measures framework.

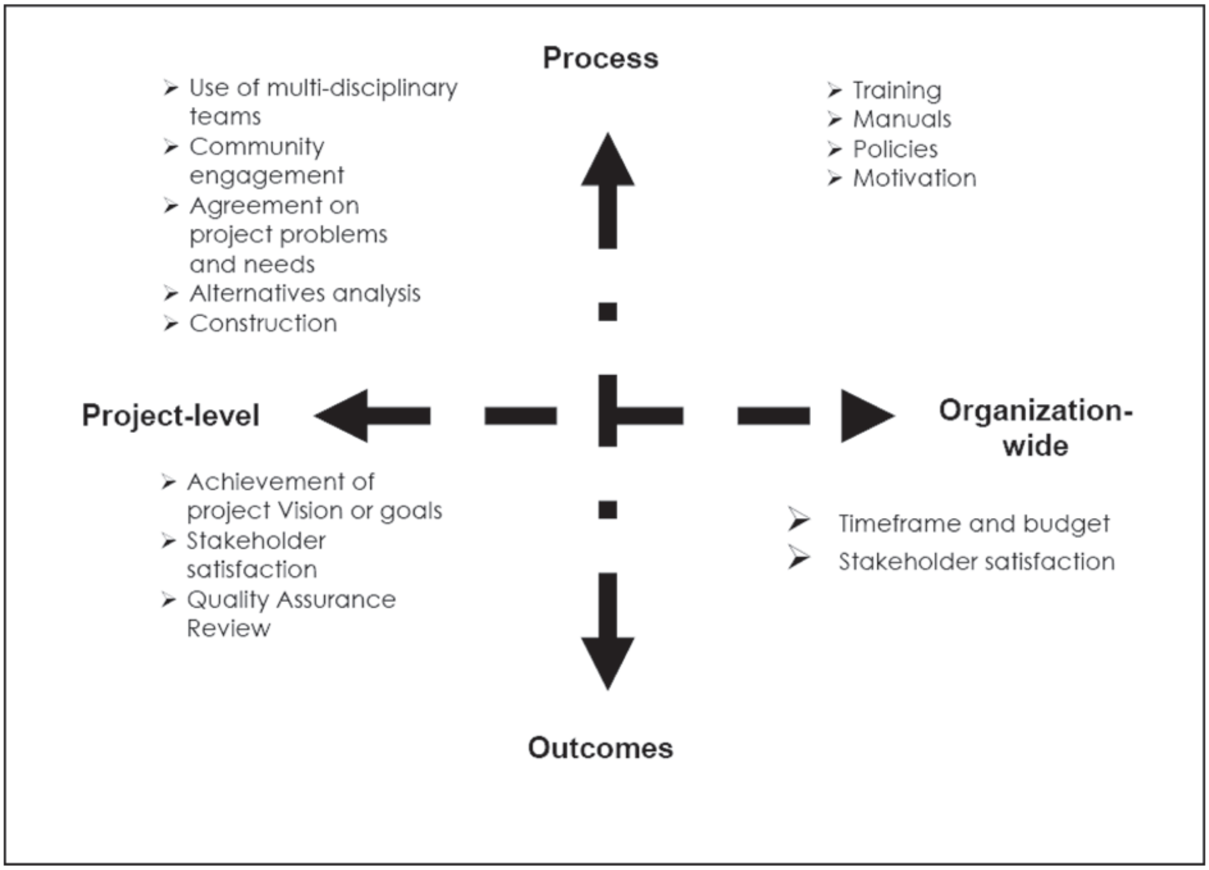


FIGURE 12 Integration of performance-based planning. *Source: NCHRP Web Document 69: Performance Measures for Context Sensitive Solutions: A Guidebook for State DOTs (54).*

Further, the guidance contains an appendix with a variety of relevant performance measures.

The customer-oriented focus of performance-based planning can help project managers and their teams to do their jobs better by maintaining a focus on the whole range of customer needs for transportation projects. Performance-based planning can be used to evaluate the CSS/CSD process and outcomes at both the project and agency levels (Figure 12).

VALUE ENGINEERING

The value engineering (VE) process is a powerful decision-making process, as using the common language of functions enables an interdisciplinary team to communicate more effectively to arrive at a supportable decision. VE is extremely useful to define the project concept, as the process of identifying the functions associated with the project objectives ensures that all participants clearly understand how the project decision-making process affects these objectives. This process can eliminate confusion and conflicting viewpoints among stakeholders and reduce the overall time to reach an optimal solution. VE is being used to engage stakeholders to—

- Establish project scope
- Fast track project development
- Improve interagency communications
- Bridge institutional borders
- Better balance the needs of road users and those of the community or the environment
- Reach consensus on difficult issues (*54*).

Relation to CSS/CSD

It is important to understand how the CSS/CSD and VE processes are related.

- Both are goal-driven processes with important common objectives.
- Both place a high value on customer satisfaction, stakeholder values, and delivery or maintenance of safe facilities.
- Both stress efficient and effective use of resources and aligning investments to produce the "best" outcomes or most "quality" for the money.
- Both are open to a broad interpretation of what is "best" and face challenges in measuring performance in more difficult to quantify areas.

- Both share an emphasis on transparency, interdisciplinary teams and perspectives, and analytical evidence-based decision making.
- Both employ processes that examine multiple alternatives with the end goal of achieving consensus on the ultimate decision.
- Both seek to optimize functions that can be delivered for the cost.
- Both seek to improve value and quality and take a broader "life cycle" view of an alternative.
- Both examine the use of flexibility in design to increase community, aesthetic, and environmental qualities through the assessment of risk.
- Both rely on interdisciplinary teams to achieve desired outcomes.
- Both emphasize creative and innovative solutions to improve the final design (*55*).

A comparison of value engineering steps with those undertaken in a CSS/CSD approach reveals similar steps in both processes (Table 9). Figure 13 illustrates how sections of the VE process can feed needed inputs to the CSS/CSD process.

TABLE 9
COMPARISON OF VE AND CSS/CSD PROCESSES

Value Engineering Steps	Similar Steps in CSS/CSD Project
(pre-study): Selection of the projects, processes, or elements for evaluation	DOT may decide to apply CSS approach to all projects. Major projects often get more extensive process.
Investigation: Background information (context is one factor), function analysis, team focus (WSDOT includes stakeholders)	Convene team, including stakeholders Investigate, learn about context, understand and discuss purpose and need, functions
Speculation: Creative, brainstorming, alternative proposals	Listening, brainstorming, alternative proposals
Evaluation: Analysis of alternatives, what are life-cycle cost impacts, which delivers highest value overall?	Understand tradeoffs. Reach consensus, if possible, on alternative delivering the most value to the public
Development: Develop technical and economic supporting data	Document decisions and why they were chosen
Present recommendations/findings. Fair evaluation.	Present arguments
Implementation of VE recommendations	Implementation of CSS recommendations—sometimes a commitment tracking system provides support
Audit: Review of completed results, accomplishments, and awards.	Audit: Review of completed results, accomplishments, and awards.
(post-study)	(post-study)

Source: Venner et al. (*55*).

One of the challenges in using VE principles to make trade-off decisions in design is associated with the difficulty in monetizing key factors under consideration (e.g., quality of life factors). However, some agencies have made attempts at this quantification. The Victoria Transportation Policy Institute has produced a number of publications that begin to monetize environmental and community quality of life factors related to transportation investments. The Utah DOT also includes "user impacts" in its definition of life-cycle cost. However, even without monetization of costs, the use of interdisciplinary teams with members of the public and resource agencies help ensure that qualitative CSS/CSD considerations are incorporated into the VE process (*55*).

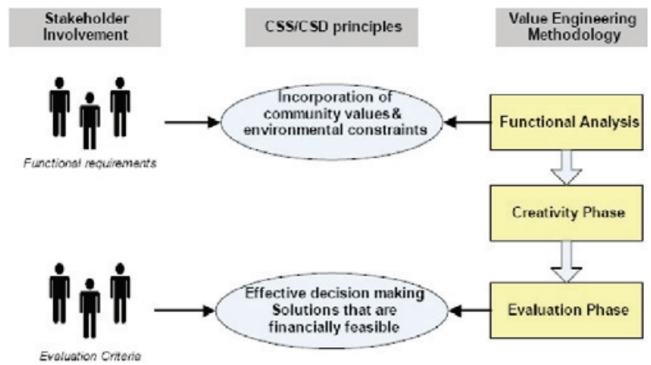


FIGURE 13 Value engineering methodology in relation to CSS/CSD inputs. *Source:* Osman et al. *(56)*.

Value Engineering Process

The systematic process used in VE is called the job plan. The VE job plan is organized into three major components: prestudy, value study, and poststudy. Figure 14 illustrates the job plan process flow. As can be seen, the value study is further broken down into six phases: information, function analysis, creative, evaluation, development, and presentation.

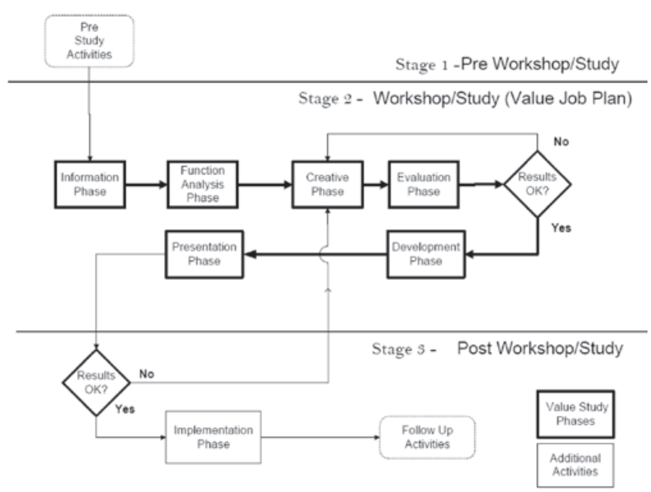


FIGURE 14 Job plan process flow. *Source:* "Value Standard and Body of Knowledge" *(57)*.

The VE focus on extracting the functional requirements and ensuring that they are integrated into the design makes its methodology well suited to examine trade-offs in design. The VE methodology can be used to determine user functional requirements, analyze these functional requirements from the abstract to the specific, and strike a balance between user functional requirements and safety constraints.

The Function Analysis System Technique (FAST) created by Charles Bytheway is an evolution of the VE process. FAST permits people with different technical backgrounds to effectively communicate and resolve issues that require multidisciplined considerations. FAST links simply expressed verb-noun functions to describe complex systems. FAST diagrams (Figure 15) are built from left to right, starting with the higher order functions that are then decomposed to functions of lower order as the diagram evolves to the right. The vertical lines delimit the scope of the VE study. Figure 16 is an example of a transportation-oriented FAST diagram.

The FAST diagram is made up of several key components. For each of these components, a representative value presented in the example FAST diagram (see Figure 16) is also provided.

- *Highest order function.* Appears outside the leftmost scope line and represents the objective or output of the basic function or subject under study. (Enhance Social Ties)
- *Lowest order function.* Appears outside the rightmost scope line and represents the function that initiates the study. (Reshape Transit)
- *Basic functions.* The functions represented to the immediate right of the leftmost scope line represent the purpose or mission of the subject under study. (Promote Street Life)
- *Objective or specifications.* Particular parameters or restrictions that must be achieved to satisfy the highest order function in its operating environment. Although they are not themselves functions, they may influence the concept selected to best achieve the basic function and to satisfy the users' requirements. (Provide Good Walking Environment)
- *Dependent functions.* Starting with the first function to the right of the basic function, each successive function is considered "dependent" on the one to its immediate left. (Provide Safe Intersections)
- *Independent functions.* These functions are not dependent on another function or method selected to perform that function. They are considered secondary with respects to the scope and critical path. (Provide Street Art) (*57*).

Figure 17 presents an example of a FAST diagram that was developed for a recent CSS/CSD-focused value planning study.

CHOOSING BY ADVANTAGES

Choosing by Advantages (CBA) was developed by the U.S. Forest Service in the early 1980s to assist decision makers in making informed choices on program expenditures. CBA differs from other decision-making systems in that it concentrates only on the difference between the advantages of alternatives

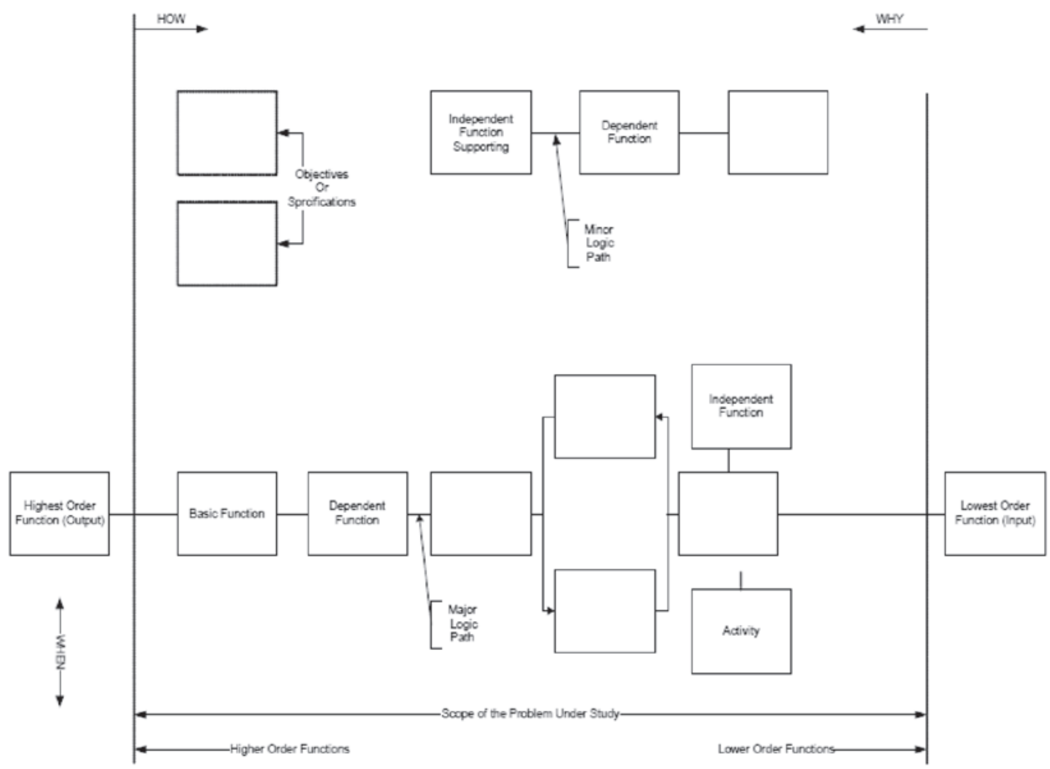


FIGURE 15 The basic FAST diagram. *Source:* "Function Analysis Systems Technique—The Basics" *(58)*.

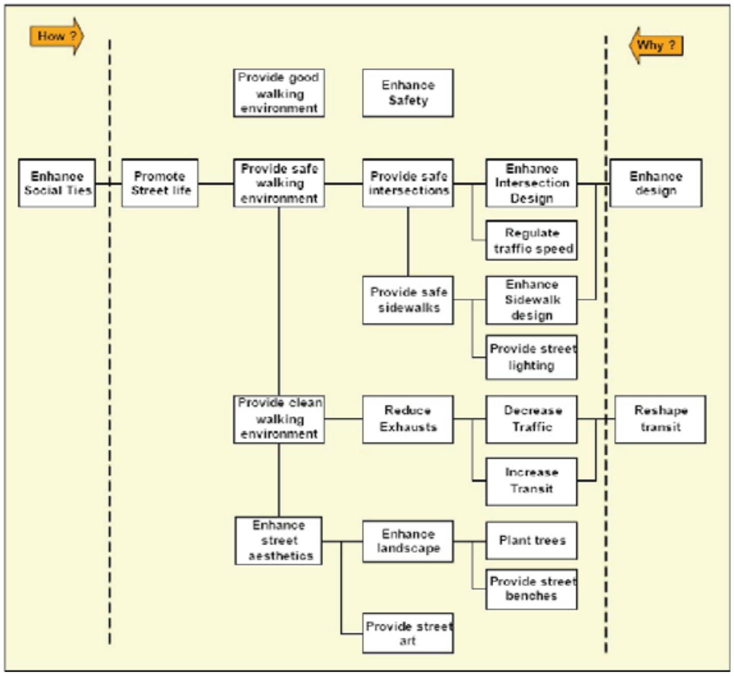


FIGURE 16 FAST diagram for enhancing social ties.
Source: Osman et al. *(56)*.

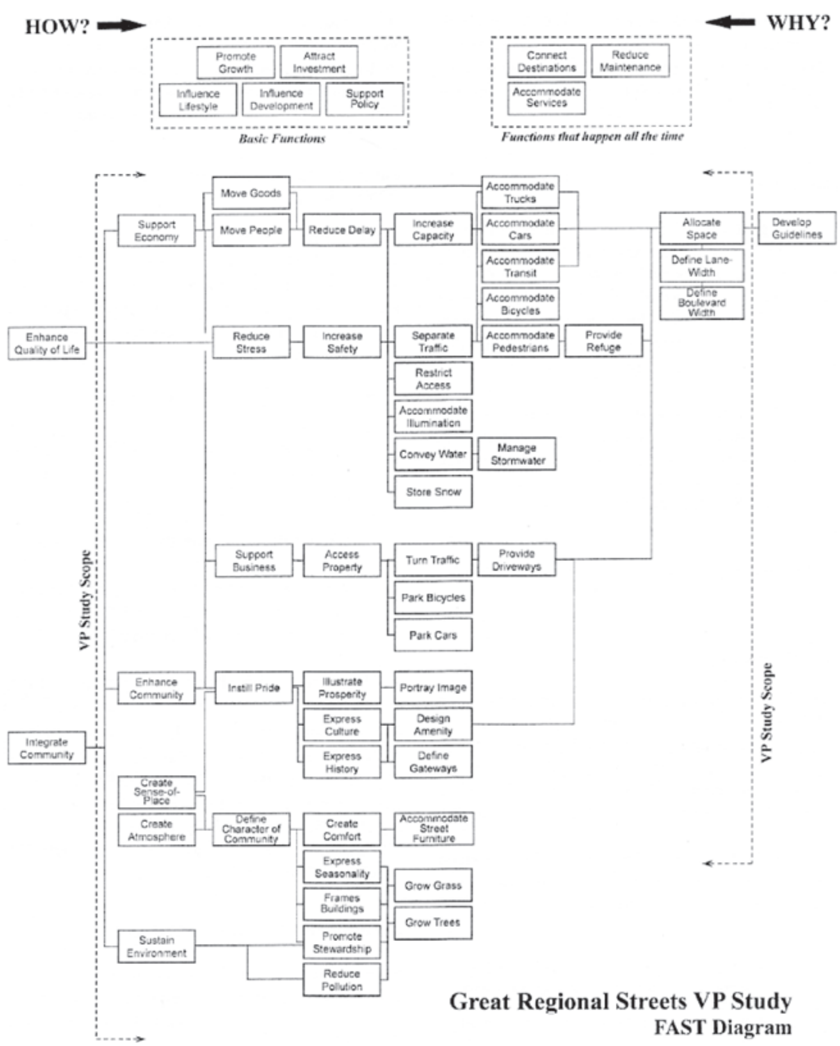


FIGURE 17 CSS/CSD-oriented FAST diagram. *Source:* Wilson *(54).*

being compared. Unfortunately, participants who have a hidden agenda have the opportunity to attempt to "game" the outcome of this decision-making process. For this reason, the use of an experienced, strong facilitator is recommended to emphasize the need for an open and fair treatment of all alternatives and to foster an environment of trust among participants.

The CBA approach involves summarizing the attributes of each alternative, deciding the advantages of each alternative, deciding the relative importance of each advantage, and developing incremental costs and incremental advantages (*52*). In the CBA vocabulary—

- Factor is an element or a component of a decision and is a container for criteria, attributes, advantages and other types of data.
- Criterion is any standard upon which a judgment is based.
- Attribute is a characteristic or consequence of one alternative.
- Advantage is a difference between the attributes of two alternatives.

CBA focuses on the differences between alternatives and determines how important those differences really are. Elements that are the same for each alternative will make no difference in the selection of the preferred alternative and therefore are not considered. This process allows the interdisciplinary team to focus discussion on the areas where there are truly differences among alternatives. At the final phase, cost is introduced to the evaluation process to establish an importance-to-cost ratio to determine which alternatives or components of larger plans provide the greatest benefit per dollar spent.

CBA is a decision-making system based on the principle that a difference between two alternatives is an advantage for one alternative and a disadvantage for the other. To simplify the decision-making process and avoid repetition, only the advantages are considered. The use of CBA provides a logical, trackable linkage between the factors used to identify the preferred alternative and the major trade-offs among the alternatives.

In its guidance on General Management Planning (*59*), the National Park System outlines the CBA process and provides a simple example of how it works. In the example, a group is planning to go camping and has to choose between several available campsites using the CBA process. Table 10 outlines the factors, attributes, and advantages for the example.

The CBA decision-making process has five basic steps.

1. Summarize the attributes of each alternative.
2. Decide the advantages of each alternative.
3. Decide the importance of each advantage.
4. Weigh costs with total importance of the advantages.
5. Summarize the decision.

The following discussion demonstrates how the CBA analysis will help the camper make a campsite selection utilizing a CBA spreadsheet (Table 11).

TABLE 10
AN EXAMPLE OF THE CBA PROCESS

CBA Definition	Example: Selecting a Campsite
FACTOR: An element, or a component, of a decision that describes differences between the alternatives. Factors are never weighted.	Factors: • water • tent spot • table • privacy It is not appropriate to decide that one of these factors is more important than the other. You need more facts about the conditions at the sites, and you need to consider the importance of the differences (advantages).
ATTRIBUTE: A characteristic, quality, or consequence of ONE factor in ONE alternative.	Attribute for the factor of water Site 8 is 60 feet away Site 19 is 260 feet away Site 23 is 150 feet away The attribute describes the situation regarding the factor water for each alternative (no values applied yet).
ADVANTAGE: A favorable difference between the attributes of TWO alternatives. Without exception, the disadvantage of one alternative is the advantage of another. A good description of an advantage is key to explaining the decision to others.	Advantage of the water factor: Site 8 is 200 feet closer Site 19 has no advantage Site 23 is 110 feet closer The least preferred water attribute is site 19 because it is farthest from water, so it has no advantage. The other alternatives are compared to this site. The closer the site is to water, the greater the advantage.

Source: General Management Plan Dynamic Sourcebook (59).

TABLE 11
CBA EXAMPLE SPREADSHEET

Factor	Alternatives					
	Site 8		Site 19		Site 23	
Factor 1 — Water						
Attributes	60 feet away		260 feet away		150 feet away	
Advantages	200 feet closer	40		0	110 feet closer	30
Factor 2 — Tent Spot						
Attributes	Moderately level		Almost level		Quite sloping	
Advantages	Moderately more level	30	Much more level	70		0
Factor 3 — Table						
Attributes	No table		No table		With	
Advantages		0		0	Table versus no table	65
Factor 4- — Privacy						
Attributes	Close sites, Near road		Screened, Distant sites		Screened, Close sites	
Advantages		0	Much more privacy due to screening and remoteness	100	Moderately more privacy due to screening	45
Total Importance of Advantages		**70**		**170**		**140**
Total Cost per Night		**$3**		**$20**		**$4**

Source: General Management Plan Dynamic Sourcebook (59).

Step 1: Summarize the Attributes of Each Alternative

The attributes for each alternative are identified in the spreadsheet by factor on the line titled "attributes." No value judgment is made regarding these attributes. For example, for Site 8 and the factor addressing water, the attribute is that water is "60 feet away."

Step 2: Decide the Advantages of Each Alternative

To determine the advantages, it is important that the group share an understanding of what attribute provides an advantage. In the example provided, everyone must first agree that being closer to water provides more advantage than being farther away. It is important to provide clear descriptions of the advantages, as they will be used later to summarize the rationale for the decision.

The least preferred attribute is underlined for each factor, and then the advantages of the other alternatives are described relative to the least preferred attribute. There is no advantage for the least preferred attribute, so leave it blank. For example, for Site 8 and the factor addressing water, the advantage is that water is "200 feet closer."

Step 3: Decide the Importance of Each Advantage

There are four considerations for deciding importance:

1. The purpose and circumstances of the decision
2. The needs and preferences of the users and stakeholders
3. The magnitudes of the advantages
4. The magnitudes of the associated attributes.

Using these four considerations, the most important advantage is determined for each factor and circled. In the example, for the factor addressing water, the fact that Site 8's water is 200 feet closer was considered the most important advantage for that factor and circled.

Next, the paramount advantage is selected from the important advantages (i.e., those just circled). It is critical to make the distinction that this is not the most important *factor*, but is the most important *advantage* (i.e., difference) between the alternatives. This paramount advantage will be used as the benchmark against which all other advantages will be compared and is assigned an importance score of 100. In the example, "much more privacy due to screening and remoteness" was selected as the paramount advantage and assigned an importance score of 100.

It is often difficult to decide which advantage is paramount. A useful technique to simplify this decision is to use the "defender/challenger" method. Two advantages are selected and the group determines which advantage is more important in the decision. The chosen advantage is then pitted against another advantage. This process continues until only one remains: the paramount advantage. Then, each of the remaining advantages will be assigned an importance score relative to the paramount advantage. The scale of importance has been established from 0 (not important) to 100 (of paramount importance). In the example, being "200 feet closer" to water was given an importance score of 40. Next, an importance score for each of the remaining advantages is determined, keeping in mind that the score must be less than the score assigned to the most important advantage. The least important advantage (identified by the underline) receives a 0. If advantages are identical, they receive the same score. In the example for the factor addressing a table, neither Site 8 nor Site 19 has a table. As this is the least preferred attribute for factor 3, both are given a score of 0.

Once importance scores have been assigned for each advantage, it is important to cross-check the logic involved to ensure that the decisions were made consistently. In the example, an importance score of 30 was assigned to both Site 23 under factor 1 and to Site 6 under factor 2. Are these really equal?

Finally, the importance scores for each alternative are totaled. If costs were equal or were not an issue, the alternative with the highest total importance score would be selected. In the example, Site 19 has a total importance score of 170, and thus has the greatest advantages.

Step 4: Weigh Costs with Total Importance of Advantages

If costs are not equal, then it must be determined whether the additional advantages justify the additional cost. In the example, Site 19 had the greatest total importance score of 170, whereas Site 8 had the lowest total score of 70; however, these advantages may not actually be worth six times the cost.

Graphing the importance-to-cost data provides a visual way to assist in decision making. A steep slope upward indicates that there is a great increase in the total importance of advantages for not much more money, and hence it may be a good value. A shallow slope, no slope, or a decreasing slope indicates that although more money is being spent, there is no corresponding increase in the importance of advantages and therefore it is not a good value. Figure 18 shows an importance-to-cost graph for the example.

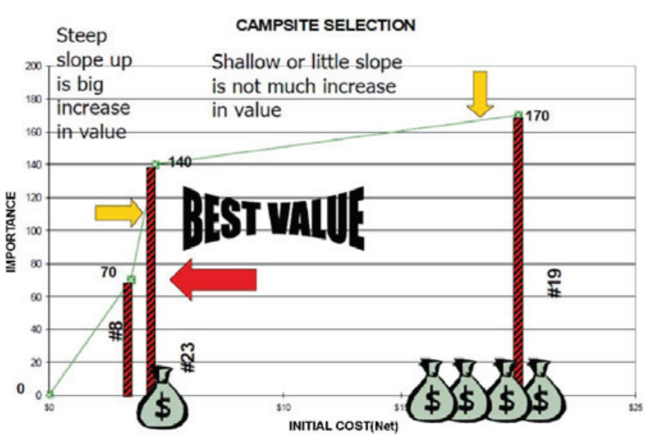


FIGURE 18 Importance-to-Cost Graph *Source: General Management Plan Dynamic Sourcebook*, *Version 2.1,* U.S. Department of the Interior, National Park Service, March 2008 [Online]. Available: http://planning.nps.gov/GMPSourcebook/GMPHome.htm.

At this point, a decision is made regarding which alternative to select. It is important to note that CBA does not provide a mechanism for making this choice; the CBA process informs the decision maker. The detailed examination of advantages also provides an opportunity to improve the preferred alternative by incorporating key advantages from alternatives not selected.

Step 5: Summarize the Decision

Using the advantage statements developed during the CBA process and notes from the discussion, a summary of the reasoning for selecting the preferred alternative is documented. Based on the example problem, Site 23 was selected because it has the following advantages: moderately more private, 110 feet closer to water, has a picnic table (other sites do not), and is the greatest value.

RISK ANALYSIS AND MANAGEMENT

Risk is perceived as the effect of uncertainty on a project or organizational objectives and represents exposure to mischance, hazards, and the possibility of adverse consequences (*59*). Risk tolerance is the varying degrees of risk organizations or stakeholders are willing to accept. A risk can be acceptable for inclusion on a project when the risk is within acceptable tolerance and is balanced by a desirable benefit. For example, it may be desirable to use 11-foot lanes on a project in order to free up enough room in the roadway cross section to provide bike lanes. A risk analysis may be used to support decision making regarding the trade-offs between various alternatives.

One of the most common ways to account for risk and uncertainty in engineering design is through a factor of safety. However, this approach does not provide any quantitative idea of the risk in a particular situation or trade-off, can result in unnecessary overdesign, and still leaves uncertainty for decision makers. Ideally, such decisions are to be taken in an environment of total certainty, wherein all the necessary information is available for making the right decision and the outcome can be predicted with a high degree of confidence. In reality, most decisions are taken without complete information, and therefore give rise to some degree of uncertainty in the outcome (Figure 19).

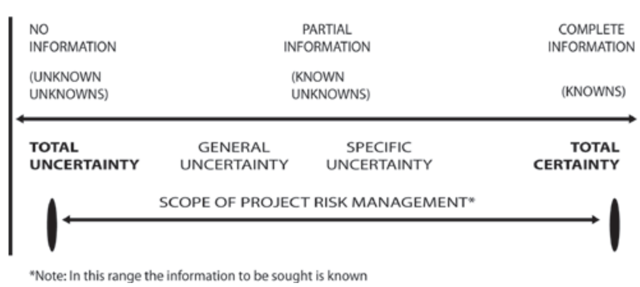


FIGURE 19 The uncertainty spectrum. *Source:* Wideman *(60).*

Risk elements that tend to attract or determine the response attitudes of decision makers include the following:

- Potential frequency of loss
- Amount and reliability of information available
- Potential severity of loss
- Manageability of the risk
- Vividness of the consequences
- Potential for (adverse) publicity
- Ability to measure the consequences
- Whose money it is (*60*)

The goals of risk analysis and management are to—

- Increase the understanding of the project;
- Identify the alternatives available;
- Ensure that uncertainties and risks are adequately considered in a structured and systematic way, which allows them to be incorporated into the planning and project development process; and
- Establish the implications of risk on all other aspects of the project through direct examination of project uncertainties (*53*).

The consequences of risk can be shared by multiple parties or shifted from one party to another. When associated with transportation projects, these concepts relate to the idea of making design trade-offs that result in changes to the risk exposure of different user groups. For example, narrowing travel lanes to provide a roadside buffer for a multiuse path is an example of shifting some risk from the pedestrian and bicyclist users of the multiuse path to the motorized users of the roadway. When coupled with the concept of Practical Solutions/Design, the risk can be shifted or shared from one project to another or between a project and the system as a whole.

This section will examine three different treatments of risk, from the project management field, the risk and reliability field, and the risk management field.

Project Risk Analysis

Project risk is the cumulative effect of the chances of uncertain occurrences adversely affecting project objectives. In other words, it is the degree of exposure to negative events, and their probable consequences affecting project objectives, as expressed in terms of scope, quality, time, and cost (*60*).

The Project Management Institute (PMI) has challenged the "negative" view of risk as being too restrictive and incomplete. PMI believes that risk is essentially "neutral" and represents both opportunities and threats. Under this approach, accepting risk leads to either a positive or a negative outcome, depending on the application of risk management (*61*).

Project risk analysis is a four-step process (Figure 20). First, the project objectives are determined; second, risks associated with the project are identified; third, the risks are prioritized; and fourth, control measures are identified to deal with high-priority risks. Often, a fifth step is included to document and communicate the risk determination.

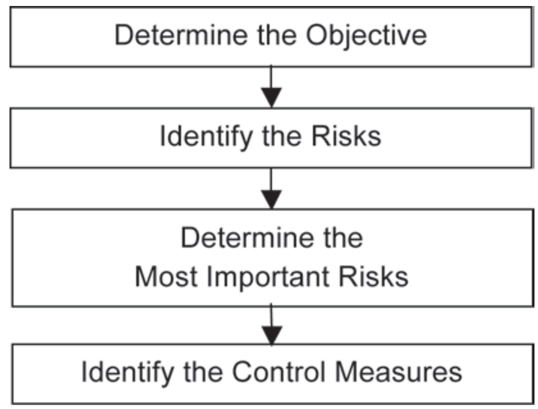


FIGURE 20 Project risk analysis. *Source:* Well-Stam et al. *(62).*

Determine the Objective

The P&N typically describes the objective(s) of the project.

Identify the Risks

This phase consists of identifying all of the possible risks that may significantly affect the success of the project. Conceptually, risks may range from high impact/high probability to low impact/low probability. Note that combinations of risk may together pose a greater threat than each risk individually.

A risk breakdown structure (RBS) (Figure 21) identifies categories and subcategories of risk. Once an RBS has been developed for a type of project, it can be reused on similar projects to remind participants in a risk identification exercise of the potential sources of risk. Similar to RBS, a risk identification checklist can be developed based on historical project information and expert knowledge (*61*).

Another input to the risk identification task can be diagramming techniques, intended to help identify where risks may affect a project. Several types of diagramming are useful:

- *Cause and Effect Diagram.* Also known as Ishikawa or fishbone diagrams, these are useful for identifying the causes of risk. (Figure 22).
- *System or Process Flow Chart.* These show how various elements of the project interrelate.
- *Influence Diagram.* These graphical representations show causal influences, time ordering of events, and other relationships among variables and outcomes (*61*).

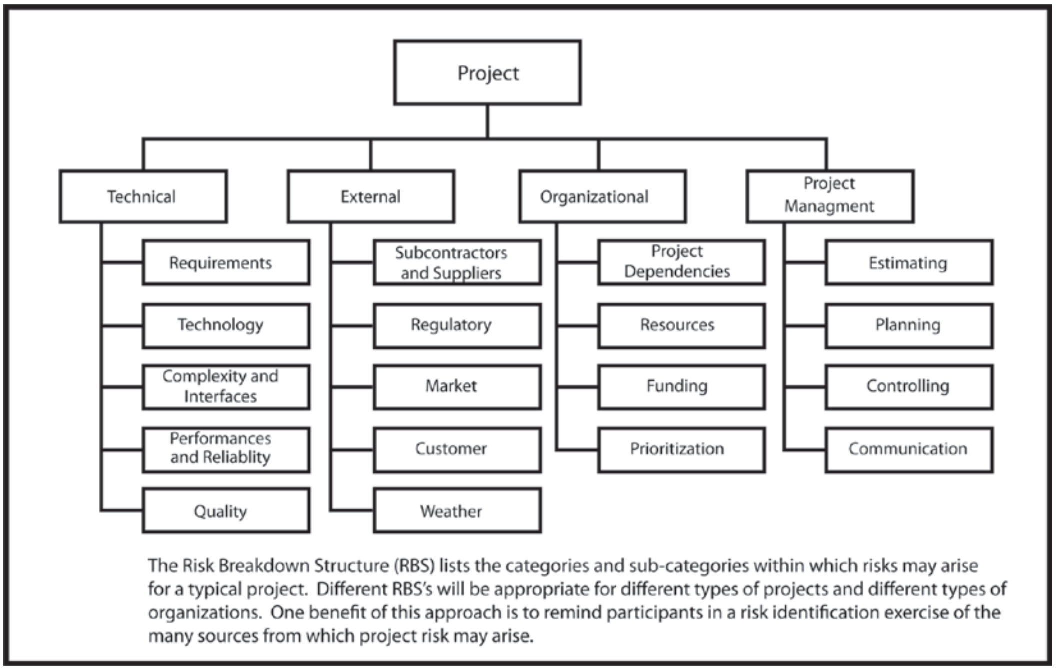


FIGURE 21 Example of a simple risk breakdown structure (RBS). *Source: A Guide to the Project Management Body of Knowledge (PMBOK Guide) (61).*

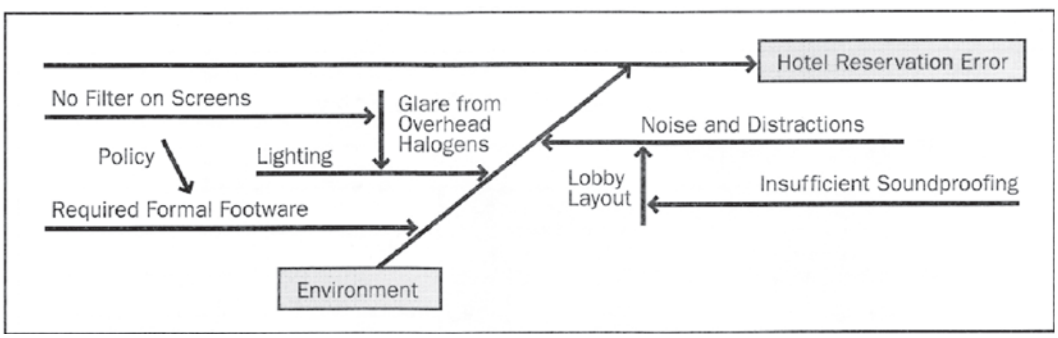


FIGURE 22 Example cause and effect diagram. *Source: A Guide to the Project Management Body of Knowledge (PMBOK Guide) (61).*

Several risk identification techniques have been developed for project planning:

- *Brainstorming.* An interdisciplinary team of experts who are not part of the project team generate a comprehensive list of potential project risks under the leadership of a facilitator. This is a simple but effective approach to help participants think creatively in a group setting without fear of criticism.
- *Delphi Technique.* Project risk experts participate in this exercise anonymously. A trained facilitator uses a questionnaire to solicit ideas about project risks. The responses are then summarized and recirculated to the experts to elicit further comment. This process is repeated until consensus is reached.
- *Interviewing.* A risk analyst interviews key project participants, stakeholders, and outside subject matter experts to develop a list of project risks.
- *Root Cause Analysis.* This technique identifies a problem, determines the underlying cause, and prepares a preventative action (*61*).
- *SWOT Analysis.* This process evaluates a project with regard to its strengths, weaknesses, opportunities, and threats (SWOT) and provides a framework for reviewing a project or specific decision. These factors are typically identified through brainstorming, and the structure of the analysis requires participants to focus on proactive thinking, rather than relying on habitual or instinctive reactions. A SWOT analysis starts with the identification of a projects goals and objectives. In transportation planning, these have typically been stated in the P&N document created as part of the NEPA process. Strengths and weakness are related to factors internal to the project, whereas opportunities and threats are related to factors external to the project.

• *Sensitivity Analysis.* This analysis seeks to place a value on the effect of changing a single variable within a project by analyzing that effect on the overall project. Uncertainty and risk are reflected by defining a likely range of variation for each component of the alternative. The impacts of these variations can then be understood in the overall context of the project (*60*).

When using a process that does not control for participant bias, such as the Delphi Technique, the bias of the participants must be taken into consideration to make sure there are no blind spots in the process. Regardless of the risk identification technique used, it is also vitally important to document the assumptions made regarding the project and identified risks. The validity of these assumptions needs to be revisited at key points during the project development process.

Project risk analysis is not a static event. Risks can either be overcome or decrease as a result of measures being implemented. As such, the risks associated with trade-offs must be reexamined at key points in a project to ensure that the analysis that underlies the decision is still valid after a particular trade-off has been accepted or a mitigation measure put into place. Evaluation of risk is a continuing, integrative function of the project life cycle.

Prioritize the Risk

During the identification process, a number of risks may emerge. It is unproductive to focus attention on all of the risks that have been identified; priority must be given to the most significant risks in order to evaluate the trade-offs associated with them. A risk management matrix provides a systematic approach to analyzing and addressing risks and ensures that all participants address risk management from a common perspective (*63*). The two most common methods to assess risk in a qualitative manner are assigning points to the most significant risks, and assessing probability and consequence separately using numbers.

The assigning points method has some ground rules to prevent one person from exerting a high degree of influence on the total by assigning all of the points to a single risk or diluting the process by assigning equal points to each of the risks. Figure 23 shows a sample risk matrix created using this method. In this example, each participant was given 100 points to assign to 10 different identified risks, with points to be assigned to a minimum of 3 risks and a maximum of 7 risks. To determine the prioritization of the risks identified, the points are added up for each risk and the risks are ranked by the number of points assigned to them.

In the assessing probability method, the risk is divided into two concepts: probability and consequence. Risk equals the probability assigned, multiplied by the consequence. This approach does not use an absolute quantification of probability and consequence; rather, the assessment uses a simple classification scheme represented by a numeric scale. It is important to make sure the scale contains an even number of values to force a choice, as no neutral or midpoint value is available. In the risk matrix shown in Figure 24, both the probability and consequence are assessed on a scale of 1 to 4. The probability classifications are 1—unlikely (5%), 2—possible (25%), 3—likely (75%), and 4—nearly certain (95%). The consequence classifications are 1—insignificant, 2—minor, 3—moderate, and 4—major. The risk with the highest risk score, in this case 12, is ranked as the first priority. A scale of 1–10 for the classification schemes is also common, depending on the complexity of the project.

Risk Participants	1	2	3	4	5	6	7	8	9	10	Points per Participant
A	10	5	0	10	0	0	0	25	30	20	100
B	5	10	30	0	0	15	10	0	30	0	100
C	10	25	15	20	0	0	5	0	5	20	100
D	5	20	17	15	33	10	0	0	0	0	100
E	5	18	20	7	20	30	0	0	0	0	100
Total	**35**	**78**	**82**	**52**	**53**	**55**	**15**	**25**	**65**	**40**	**500**
Risk Rank	8	2	1	6	5	4	10	9	3	7	

FIGURE 23 Sample risk matrix using the assigning points method. *Source:* Well-Stam et al. *(62).*

Description of Risk	Probability x	Consequence =	Risk	Priority
More design modifications than planned	4	1	4	3
More land needed	3	4	12	1
Additional sound-proofing facilities	4	2	8	2
Removing unexpected obstacles	2	1	2	4

FIGURE 24 Sample risk matrix using the assessing probability and consequence method. *Source:* Well-Stam et al. *(62).*

Each of the methods for qualitatively prioritizing risk has advantages and disadvantages, as summarized in Table 12. A further drawback to the assessing probability and consequence method is that it equates risk of a high-probability, low-damage event with that of a low-probability, high-damage event. Clearly, in real life these two events may not amount to the same risk (*64*).

TABLE 12
ADVANTAGES AND DISADVANTAGES OF THE DIFFERENT METHODS

Assigning Points	Probability and Consequence Classes
Advantages	*Advantages*
Quick; it is not necessary to assess all of the risks individually Provides a good first insight into priority	Forces one to make a distinction between probability and consequence Less room for implicit inclusion of factors other than probability and consequence
Disadvantages	*Disadvantages*
Room for implicit inclusion of factors other than probability or consequence	Very time-consuming; each risk must be individually assessed

Source: Well-Stam et al. (*62*).

Identify Mitigation

The process of identifying mitigation strategies deals directly with risk response. These risk mitigation strategies form the response component of a risk management strategy (*62*).

Document and Communicate Risk

Final documentation is a vital part of project risk analysis so that appropriate trade-off decisions can be made with full knowledge of the apparent risks involved. Either the residual risks must be accepted or the alternative must be abandoned. Further, the purpose is to build a base of reliable data for the continuing evaluation of risk on the current project, as well as for improving the data for all subsequent projects (e.g., developing an improved RBS).

Risk and Reliability Analysis

Figure 25 illustrates the overall philosophy of decision making. This philosophy presents decision making through a triangle whose three vertices are benefit-cost theory, decision theory, and sustainability theory. As shown, risk and reliability analysis occupies a central place in the interaction of the concepts of certainty and uncertainty, efficiency and equity, and single and collective decision making. The relative importance of the vertices can change based on what a society values. The greater focus on sustainability and equity today results in decision making becoming participatory. To emphasize the importance of these principles, they are placed at the apex of the decision triangle. The ultimate goal of risk and reliability analysis is to reduce uncertainty and thereby reduce risk (*64*).

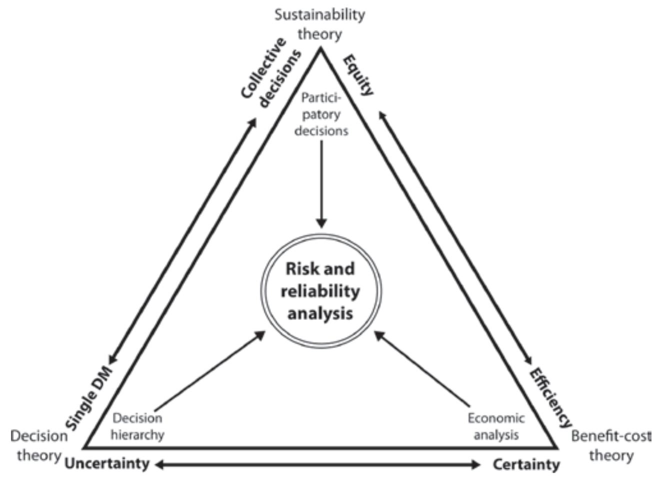


FIGURE 25 Decision triangle. *Source:* Singh et al. *(64).*

Engineering projects are always subject to a risk of failure to achieve their objectives. There are various definitions of risk for different purposes, including the probability of failure, the reciprocal of the expected length of time before failure, the expected cost of failure, and the actual cost of failure. Risks are possibilities that human activities or natural events lead to consequences that affect the intended objectives. In general terms, risk can be defined as the potential loss resulting from the combination of hazard and vulnerability. Reliability, the complement of risk, is defined as the probability of nonfailure.

One of the dilemmas in risk assessment is defining "acceptable risk." The acceptability depends on the context in which the risk occurs and the availability of financial resources. Logically, a decision maker will choose the optimum mixture of risk, cost, and benefit, and might be willing to take a higher risk only if it is associated with either less cost or more benefit.

Risk and reliability analysis is a four-step process: hazard identification, risk assessment, risk management, and risk communication (Figure 26).

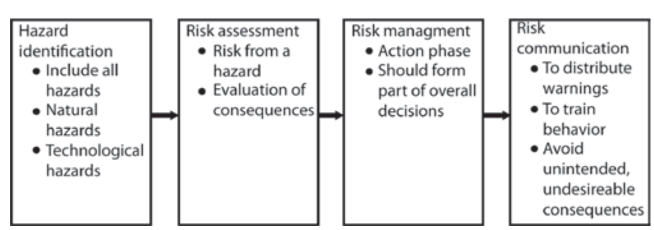


FIGURE 26 Risk and reliability analysis. *Source:* Singh et al. *(64).*

Hazard Identification

Hazard identification depends on knowledge, experience, forecasting, engineering judgment, and imagination to adequately identify potential hazards. The key is to include all hazards, however unlikely they may be.

Hazard identification encompasses a compilation of possible failures, each with a set of parameters for consequence modeling. The types of hazards to be managed are—

1. Natural hazards (from the physical environment)

2. Technological hazards (from human-created technology)

3. Social hazards (from within human society)

The events that produce hazards are characterized by their magnitude, and an event is termed hazardous when the magnitude crosses over a threat-producing threshold (*64*).

Risk Assessment

Risk assessment is a systematic, analytical method used to determine the probability of adverse effects. After the hazard-producing events have been identified and their data have been collected, the risk can be assessed. In this step, the consequence of a particular risk is evaluated with regard to its impact on the overall project objectives. Fundamental to risk modeling is an assessment of uncertainties, both quantifiable and unquantifiable. It is simply not possible to deal with every kind of risk. As such, only the kinds of risk that can be estimated quantitatively, at least in principle, need to be considered.

Risk Management

Risk management is a systematic process of making decisions to accept a known or assumed risk and the implementation of actions to reduce the harmful consequences or probability of occurrence. As part of risk management, these risks must be assessed and a proper response for mitigating them developed. Risk mitigation is the action phase of risk management wherein the best strategy is selected.

Risk Communication

Risk communication is intended to communicate all of the consequences associated with a trade-off regarding the existence and nature of a threat, the seriousness of risk, and details of the steps that can be taken to mitigate its effects. For risk communication to be successful, all parties must be open to the information presented. However, if the action required to mitigate risk will cost money or require people to change habits, the information is likely to be rejected. Common ways of communicating risk are through mass media, public meetings, and written material.

Risk Management

An agency's management structure and project development processes, including use of design criteria, design decision making, and documentation practices, are all important aspects of risk management. Full application of the CSS/CSD design processes discussed here supports risk management, as demonstrated in the following:

- *Consider Multiple Alternatives* – Good risk management practices involve thorough consideration of multiple alternatives, including explanation for why a full standard design may not be possible or desirable and what the alternatives are. This practice highlights the concept of design as representing discretionary choices.
- *Evaluate and Document Design Decisions* – Design reports document the expected operational and safety performance of the proposal. Stakeholder engagement, including developing, evaluating, and discussing different alternatives, requires documentation. All such documentation should be readily available to place in project files for later reference. Special care is to be taken when a new or creative concept is proposed, such as a diverging diamond interchange or traffic-calming feature. If a design exception is needed, documentation must be complete, including a full description of the need for the exception based on adverse effects on community values, the environment, and so on.
- *Maintain Control Over Design Decision Making* – The owning agency must stay in control of decisions regarding basic design features or elements. Active stakeholder involvement and input does not translate to abrogating the agency's responsibility of to make fundamental design decisions.
- *Demonstrate a Commitment to Mitigate Safety Concerns* – When a design exception or unusual solution is proposed, plan completion could focus on mitigation. Decisions to maintain trees along the roadside, for example, may be accompanied by special efforts to delineate the edgeline or trees, implement shoulder rumble strips, or provide guardrails or other roadside barriers.
- *Monitor Design Exceptions to Improve Decision Making* – A few states make a special effort to keep a record of design exceptions by location, committing to review their safety performance over time. The intent is not to second-guess a decision, but to build on and improve a knowledge base for future decisions regarding design exceptions (*4*).

Psychology of Risk Perception

It is vital to understand how the public perceives risk in order to understand how to communicate regarding the analysis and mitigation of risk. Research into the psychology of risk perceptions by U.S. psychologists Paul Slovic and Vince Covello indicates—

1. People do not demand zero risk. They consciously and subconsciously take risks every day.

2. People's judgments of degrees of risk are not coincident with most methodologies for measuring risk statistically. The public may greatly underestimate familiar risks while greatly overestimating unfamiliar risks.

3. A variety of emotional, not logical, factors control typical risk perceptions.

4. Once established, risk perceptions are extremely hard to change. New information may be absorbed by the intellect, but it is not readily absorbed at an emotional level.

5. Risk perceptions reside fundamentally at an emotional level (*60*).

These insights suggest that the traditional approach to risk communication, which relies on providing rational, statistically based information alone, may miss the mark. Because the fundamentals of risk perception are emotional and not rational, the primary focus of project risk management communications should be to establish trust in the organization, rather than to educate the public about the engineering fundamentals underlying a decision. Rather than try to change the public's risk perception, which the research states is extremely hard to do, this approach seeks to change public attitudes toward those who are being held responsible for creating and managing the risk (*60*).

SAFETY

Promoting safety and safe travel is at the core of all transportation planning and design, where safety can be understood as a measure of the freedom from unacceptable risks of personal harm. The basic principles and guidelines that influence much of what happens in project development are founded on professional principles of encouraging safe design. TEA-21 increased emphasis on safety by identifying safety and security as one of seven key planning factors that must be considered in statewide and metropolitan planning processes, which was continued with the next authorization bill, SAFETEA-LU. As such, special attention must be paid to trade-offs that may influence the potential of an alternative. Several key areas provide insight into how to address these trade-offs: the field of organizational accident analysis and prediction, safety-conscious planning, the interactive highway safety design manual, and the new *Highway Safety Manual.*

Organizational Accidents

The field of organizational accident analysis and prediction centers on the identification and mitigation of risk. A paramount consideration when dealing with the evaluation of trade-offs in roadway design is the preservation of safety in the resultant design. As such, some background on the theory of accidents is appropriate to understand how they occur, what must be done to prevent them, and how an organization must react to create an environment that promotes safety-conscious decisions.

Theory

The pioneering work done by Reason (*65*) serves as the underlying basis for much of the modern work dealing with organizational accidents. Reason's paper "The Contribution of Latent Human Failures to the Breakdown of Complex Systems" followed on the heels of several high-profile disasters in a wide range of endeavors: nuclear power plants, chemical installations, spacecraft, roll-on-roll-off ferries, aircraft, offshore oil platforms, and railway networks. Reason surmised that even though these disasters may appear unrelated, they share several important factors:

1. The accidents occurred in a complex environment that possessed elaborate safety devices and protections.

2. The accidents were caused not by a single failure, but by a conjunction of several diverse sequences, each necessary but not sufficient to cause the event by itself.

3. Human failures, not technical failures, were typically the root cause.

Weick (*66*) expanded on this idea of linked events, postulating that to anticipate and forestall disasters is to understand regularities in the ways small events can combine to have disproportionately large effects. The central question of accident investigation is how the defenses were breached (Figure 27). Reason (*67*) identifies three sets of factors that are responsible: human, technological, and organizational.

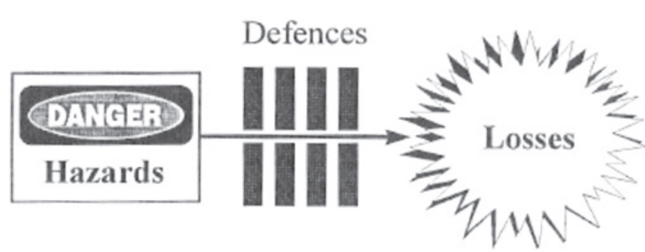


FIGURE 27 The relationship between hazards, defenses, and losses. *Source:* Reason *(67).*

Reason (*65*) further observed that human operators are increasingly remote from the processes that they nominally govern, and that most of the time these operators are simply monitoring the system to ensure that it functions within acceptable limits. By comparison, as much of the underlying rationale for design standards is removed from design manuals, designers who do not understand the fundamentals underlying the criteria are acting in a similar manner.

Reason (*67*) identified two primary ways in which humans caused breakdowns in complex systems: active and latent failures. Active failures involve errors or violations that have an immediate effect, whereas latent failures are tied to decisions or actions that later result in a breach of the system's defenses. Figure 28 depicts how both active and latent failures can combine to "holes" in even a layered defense. When the correct sequence of events lines up with these holes, an accident trajectory can pierce the defenses, resulting in an accident. This is often referred to as the "Swiss cheese" model.

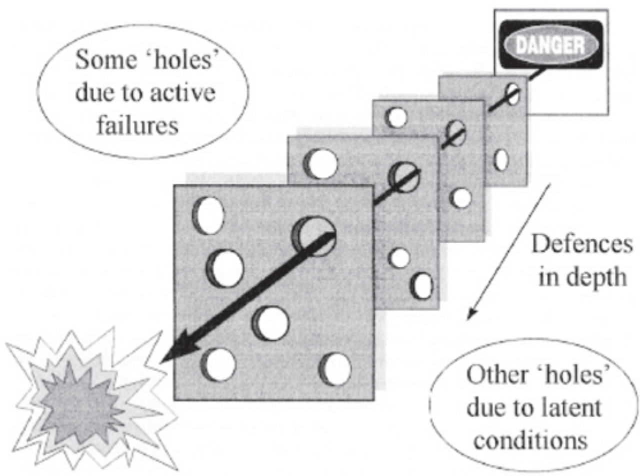


FIGURE 28 Accident trajectory passing through corresponding holes in layers of defenses, barriers, and safeguards. *Source:* Reason (*67*).

Application to Road Design

Salmon and Lenne (*68*) have directly applied the theory of organizational accidents to the field of traffic safety and roadway design. They found that Australia has been using a "systems approach" to safety over the past two decades, resulting in significant safety gains. Under this approach, safety is a product of the overall system. They point to the Australian National Road Safety Strategy 2001–2021, the Swedish Vision Zero, and the Netherlands' Sustainable Safety approaches as evidence that this approach is gaining popularity. These programs advocate a shared responsibility for safety, an appreciation of the limits of human performance and tolerance, and a forgiving road transport system. They stress that in a road safety context, elements of the system beyond road users, such as vehicle design and condition, road design and condition, and road policies, all shape driver behavior.

Reason's systems perspective model of human error and accident causation, more commonly known as the "Swiss cheese" model, is used as a basis to examine the relationship of problems with the transportation network and safety. Reason's model holds that weaknesses in the system's defenses, created by inappropriate or inadequate decisions and actions by actors at all levels of the system, allow accident trajectories to breach defenses and cause accidents. The Human Factors Analysis and Classification System (HFACS) was developed for the aviation safety domain, but has been successfully applied to other safety domains as well. It considers both the errors at the "sharp end" of the system operation and also the latent conditions involved in a particular incident or accident (Figure 29). HFACS identifies four layers of defenses onto which the active and latent failures are mapped: unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences. Many factors contribute to the latent and active failures in each layer of the defense. By mapping the data typically available for traffic crashes onto this model, it can be seen that the data available cover mainly the road user and environmental, equipment, and context (e.g., time of day) factors (Figure 30). Data covering higher level latent errors, such as poor roadway design, poor maintenance, or poor operations, are not contained in a typical crash record, so a complete picture of the accident trajectory is not available with current traffic safety data. As such, to link these factors to a particular crash, additional data mining is necessary.

Organization Types

Reason (*67*) identifies three types of organizations in relation to how they approach the idea of reforms to their processes and procedures with respect to safety:

- Pathological organizations – Use inadequate safety measures.
- Calculative organizations – Take a "by-the-book" approach to safety.
- Generative organizations – Set safety targets beyond ordinary expectations and are willing to use unconventional means to achieve them.

Westrum (*69*) emphasized that for an organization to avoid losses, it must have what he termed "requisite imagination." This is the diversity of thinking and imagining that is required to identify possible failure scenarios. This requisite imagination is typically present only in generative organizations, and its absence can leave blind spots in an organization's defenses that can result in disaster.

Until the last 20 years, most STAs would fall into the category of calculative organizations. However, with the advent of CSS/CSD, a gradual transition to generative organizations has begun. Sweden's Vision Zero, begun in 1997, aims to achieve a highway system with zero fatalities or serious injuries and is an example of a generative organization goal that requires an agency to revamp its approach to engineering.

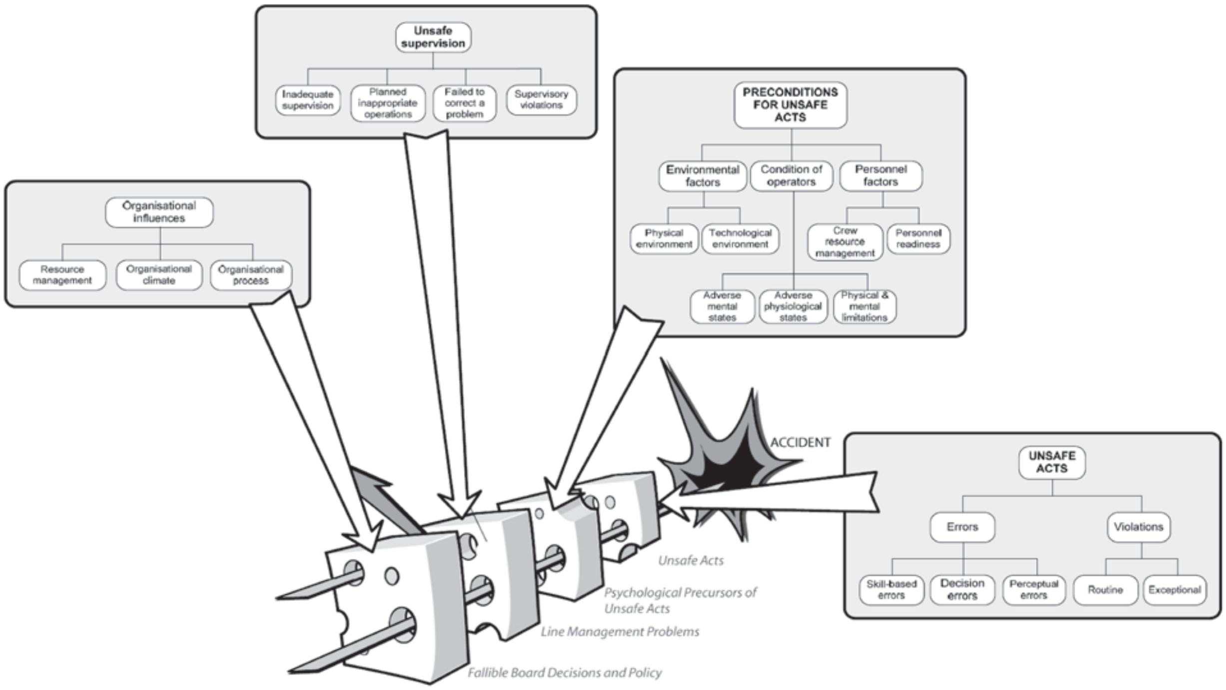


FIGURE 29 HFACS mapped onto Reason's Swiss cheese model. *Source*: Salmon and Lenne (*68*).

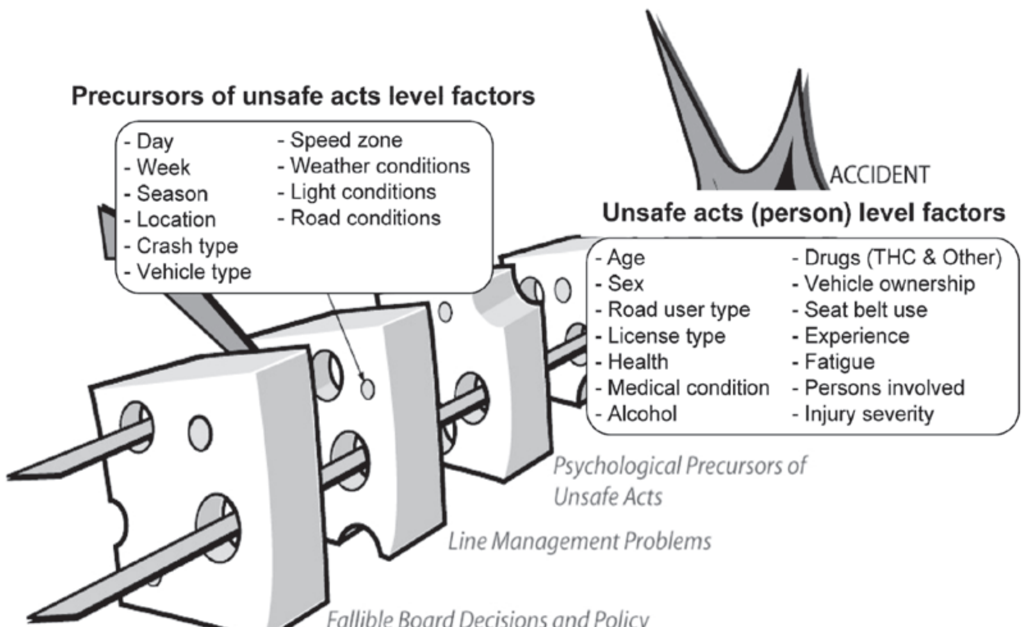


FIGURE 30 Fatal road traffic accident data mapped onto Reason's Swiss Cheese Accident Causation Model. *Source*: Salmon and Lenne (*68*).

Overview

One of the key takeaways from the work done in the organizational accident area is that many disasters occur when a combination of active and latent failures align to create an accident. When dealing with trade-offs in roadway design, the designer and decision makers must be careful to step back and look at the trade-off decisions holistically once they are made, as individual trade-off decisions that may be perfectly safe can in combination create conditions that compromise safety. Reason (*67*) identifies that a change in one system parameter must be compensated for by changes in other parameters. The current interest in three-dimensional design verification is an example of this holistic evaluation.

Safety-Conscious Planning

Although safety lies at the core of all transportation planning, the utility and role of safety measures in the planning process has been difficult to manifest in subsequent analysis, evaluation, prioritization, and system performance monitoring. The concept of incorporating safety issues into the transportation planning process in a more comprehensive way arose around the same time that CSS/CSD began to gain increasing consideration. The concept of safety-conscious planning integrates safety into all aspects of transportation planning, including setting the policy and planning context for eventual project development. Safety-conscious planning is comprehensive in the sense that it considers all aspects of transportation safety—not only infrastructure-related improvements but also enforcement and education strategies as well as enhancing emergency service response to incidents (*70*).

Substantive safety effects are currently described in two primary ways—safety performance functions (SPFs) and accident modification factors, now called crash modification factors (CMFs).

- SPFs describe the expected crash frequency for a condition or element as a function of traffic volume and other fundamental values. SPFs are usually expressed as an equation or mathematical function. The following is an example of a SPF for a roadway segment on a rural two-lane highway:

$$N_{SPF\ rs} = (\text{AADT}) \times (L) \times (365) \times 10^{(-6)} \times e^{(-0.4865)}$$

Where:

$N_{SPF\ rs}$ = estimate of predicted average crash frequency for SPF base conditions for a rural two-lane two-way roadway segment (crashes/year);

AADT = average annual daily traffic volume (vehicles/day) on roadway segment; and

L = length of roadway segment (miles) (*71*).

- CMFs describe the expected change in crash frequency (total or particular crash type) associated with an incremental change in design dimension. CMFs may be shown in tabular form or in some cases as a simple function. They are expressed as a decimal, with a CMF less than 1.0 indicating a lower crash frequency and a CMF greater than 1.0 indicating a higher frequency (*23*).

The availability of new tools to quantify safety effects opens up the possibility of moving to performance-based design. Although the conventional approach provides design consistency and uniformity, code-based design and applications may decrease in importance, yielding to performance-based design. Under performance-based design, designers will apply analytical procedures to quantify or estimate the possible trade-offs and to consider changes and variations in physical dimensions (*72*).

Road Safety Audits

Road safety audits (RSAs) are formal procedures for assessing the accident potential and safety performance of new and existing highways and streets by an independent audit team. This team considers the safety of all road users (e.g., drivers, pedestrians, bicyclists, elderly, children), considers all environmental conditions (e.g., day, night, inclement weather), and qualitatively estimates and reports on road safety issues and opportunities for improvement with the existing facility or proposed design (*73*). The objective of the RSA is to ensure that all new highways operate as safely as practicable. This objective means that safety needs to be considered throughout the design process by bringing an improved understanding of crash causes and countermeasures to bear in a proactive manner. RSAs can help produce designs that limit the number and severity of crashes, promote awareness of safe design practices, and identify and correct safety issues before projects are built (*74*). Experience with RSAs in the United States shows that the RSA team often uncovers safety concerns that a traditional safety review would have missed.

An RSA and a safety review are two different processes (see Table 13). Some key differences are that a, RSA is conducted by an independent, interdisciplinary team and generates a formal response report (*75*).

TABLE 13
DIFFERENCES BETWEEN ROAD SAFETY AUDIT AND TRADITIONAL SAFETY REVIEW

What is the difference between RSA and Traditional Safety Review?

Road Safety Audit	Traditional Safety Review
Performed by a team independent of the project	The safety review team is usually not completely independent of the design team
Performed by a multi-disciplinary team	Typically performed by a team with only design and/or safety expertise
Considers all potential road users	Often concentrates on motorized traffic
Accounting for road user capabilities and limitations is an essential element of an RSA	Safety reviews do not normally consider human factor issues
Always generates a formal RSA report	Often does not generate a formal report
A formal response report is an essential element of an RSA	Often does not generate a formal response report

Source: FHWA Road Safety Audit Guidelines (75).

FHWA has developed the *FHWA Road Safety Audit Guidelines* to assist agencies in developing policies and procedures for conducting RSAs. The guide outlines the typical steps associated with undertaking an RSA (see Figure 31). To support this approach, FHWA has developed an RSA training course through the National Highway Institute (FHWA-NHI-380069 *Road Safety Audits/Assessments*), which can be accessed at http://www.nhi.fhwa.dot.gov.

FIGURE 31 Typical RSA steps. *Source: FHWA Road Safety Audit Guidelines (75).*

All RSAs must have the following key elements:

- Formal Examination – Design components and associated operational effects are formally examined from a safety perspective.
- Team Review – RSAs conducted are by teams of at least three auditors.
- Independent RSA Team – Audit team members are independent of the design team.
- Qualified Team – Auditors have appropriate qualifications. An understanding of the *AASHTO Roadside Design Guide*, positive guidance techniques, access management, and crash analysis is strongly suggested (*76*).
- Focus on Road Safety – The principal focus of an RSA is to identify potential safety issues, not to serve as a compliance review.
- Includes All Road Users – All appropriate vehicle types, modes of transportation, and road users are to be included in the RSA.
- Proactive Nature – RSAs need to consider all potential safety issues, not only those that may be demonstrated by a crash history.
- Qualitative Nature – Outputs are qualitative, not quantitative, in nature. Outputs include lists of identified issues, assessments of relative risk, and suggested corrective measures.
- Field Reviews – Day and night field reviews are conducted (*75*).

During the planning and preliminary engineering phases of a project, an RSA team can review all of the options being considered and make recommendations such as changes in horizontal and vertical alignment, provision of a median, land and shoulder width, provision of bike lanes and sidewalks, and provision of channelization (*75*). These recommendations can be used to improve alternatives, and the safety issues identified can be used to compare alternatives in a qualitative manner.

Prompt lists help auditors identify problem safety issues during an RSA and have been developed for the different stages of a project by FHWA. Figure 32 is an example of the prompt list provided for the planning stage audit. These lists help the RSA team identify potential safety issues and ensure that nothing is overlooked in the audit. However, care must be taken in the application of prompt lists to ensure that the RSA does not become a mechanistic exercise of checking the boxes instead of helping the auditors apply their knowledge and experience (*67*).

There is a range in the format and approach used in developing prompt lists by agencies most experienced with RSAs. The Austroads RSA Guide implements a comprehensive approach, detailing every consideration at each stage of the process, including feasibility, preliminary design, final design, pre-opening, roadwork traffic schemes, existing roads, and land use development proposals. At the other end of the spectrum is the broader approach found in the Canadian RSA Guide. This approach utilizes simple prompt lists meant to challenge the user to think about various issues, such as geometric design, traffic operations, control devices, human factors, environmental and integration, that could be found at all stages of project development. The FHWA prompt lists lean toward the broader approach (*77, 78*).

Additionally, FHWA has developed software to aid in the performance of RSAs. This software is intended to aid the auditor by providing guidance, providing a means for tracking data, generating prompt lists at appropriate levels of detail, and aiding in the preparation of the final RSA report.

Planning Stage Audit

General Topics	Design Issues	Intersections	Interchanges	Environmental Constraints	Safety Aspects Not Already Covered
1 Scope of project, function, traffic mix, road users	1 Route choice	1 Location, spacing types	1 Location, spacing	1 Surrounding terrain	Flooding, rail crossings, roadside parking, special events, emergency vehicles, rest areas, etc
2 Type and degree of access to property and developments	2 Impact of continuity with the existing network	2 'Readability' (perception) by drivers	2 Types, layouts	2 Weather, sunlight	
3 Major generators of traffic	3 Broad design standards	3 Road users, traffic mix	3 Ramps, terminal intersections	3 Noise barriers, animal fencing	
4 Staging of construction	4 Design speed	4 Design consistency	4 Design consistency	4 Animal crossings	
5 Future reconstruction projects	5 Design volume and traffic characteristics	5 Number of lanes	5 Number of lanes	5 Visual distractions	
6 Wider network effects	6 Right of way			6 Unstable land	
	7 Combination of features				

FIGURE 32 Planning stage audit prompt list. *Source: FHWA Road Safety Audit Guidelines (75)*.

Interactive Highway Safety Design Model

The IHSDM is a suite of software analysis tools for evaluating the safety and operational effects of geometric design decisions. Under its current configuration, it can assist designers in evaluating design alternative for two-lane rural highways against relevant design policy values and provide estimates of a design's expected safety and operational performance. The IHSDM—HSM Predictive Method 2010 Release Crash Prediction Module includes additional capabilities to evaluate rural two-lane highways, rural multilane highways, and urban/suburban arterials. The IHSDM currently includes five evaluation modules: crash prediction, design consistency, intersection review, policy review, and traffic analysis.

- *Crash Prediction Module*. Estimates the frequency and severity of crashes that can be expected on a highway based upon its geometric design and traffic characteristics. This module can help identify potential improvement projects on existing roadways, compare the relative safety performance of design alternatives, and assess the safety and cost-effectiveness of design decisions.
- *Design Consistency Module*. Diagnoses safety concerns at horizontal curves by providing estimates of the magnitude of potential speed differentials. This module provides a diagnostic tool for existing alignments and serves as a quality assurance check on new design alternatives.
- *Intersection Review Module*. Evaluates an existing or proposed intersection geometric design to identify potential safety concerns and suggest possible treatments to mitigate those concerns.
- *Policy Review Module*. Checks design elements for compliance with geometric design criteria. This module provides a diagnostic tool for existing alignments and serves as a "nominal safety" audit for proposed designs.
- *Traffic Analysis Module*. Estimates traffic quality-of-service measures for an existing or proposed design under current or projected traffic.

The IHSDM software may be downloaded free of charge through the IHSDM public software website at http://www.ihsdm.org/ (*79*).

Highway Safety Manual

The HSM is a resource that provides tools and safety knowledge in a format to help decision making regarding highway design based on safety performance. The HSM provides methodologies that can be utilized to analyze trade-offs across a broad range of design activities, including planning, programming, project development, construction, and operations and maintenance. Before the release of the HSM, practitioners did not have a single national resource for reliable quantitative information about crash analysis and evaluation. Although the HSM is not currently applicable to all types of facilities, it does represent the state of the art for evaluating safety trade-offs and incorporating them into the decision-making process in a technically sound and consistent manner. However, to gain full predictive benefit of the HSM procedures, the base models need to be calibrated to local conditions every 2 to 3 years. The HSM does not represent a legal standard of care, but is meant to provide guidance for evaluating safety trade-offs (*71*). Figure 33 illustrates the organization of the HSM and how each of the sections relates to the others. Figure 34 illustrates how planning, design, construction, and maintenance activities relate to the HSM.

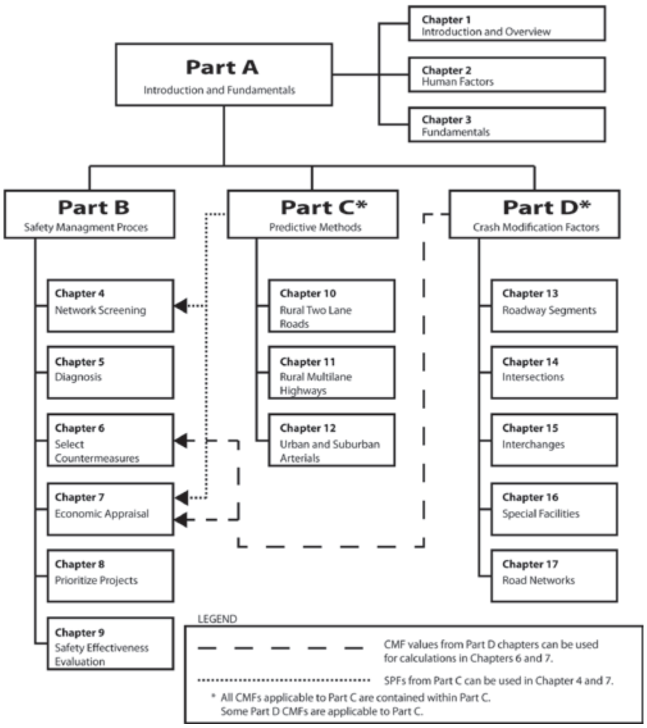


FIGURE 33 Organization of the *Highway Safety Manual.* *Source: Highway Safety Manual (71).*

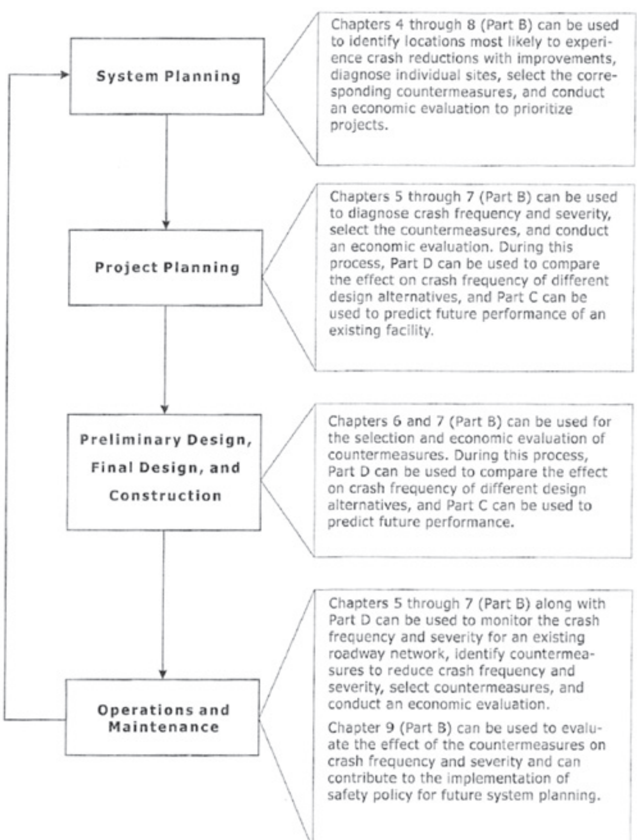


FIGURE 34 Relating the project development process to the *HSM. Source: Highway Safety Manual (71).*

The HSM has developed SPFs in Volume 2 for three facility types and for specific site types of each facility, as summarized in Table 14. In addition, a software package called HiSafe has been developed to support the predictive methods in this section of the *HSM*.

TABLE 14
FACILITY TYPES AND SITE TYPES INCLUDED IN PART C OF *HSM*

			Intersections			
			Stop Control on Minor Leg(s)		Signalized	
Facility Type	Undivided Roadway Segments	Divided Roadway Segments	3-Leg	4-Leg	3-Leg	4-Leg
Rural Two-Lane Roads	✓		✓	✓		✓
Rural Multilane Highways	✓	✓	✓	✓		✓
Urban and Suburban Arterial Highways	✓	✓	✓	✓	✓	✓

Source: Highway Safety Manual (71).

The HSM has also developed CMFs for different countermeasures, which are found in Volume 3. They are organized by roadway segments, intersections, interchanges, special facilities and geometric situations, and road networks. The SPFs and CMFs developed in the HSM use the same base conditions and therefore are compatible.

SafetyAnalyst

SafetyAnalyst provides a set of software tools to help designers perform site-specific highway safety analyses, including many of the procedures that are presented in HSM Part B. It allows the user to evaluate trade-offs in a decision-making process using several screening tools. More information on SafetyAnalyst can be found on its website at http://www.safetyanalyst.org.

SafetyAnalyst can not only identify accident patterns at specific locations and determine whether those accident types are overrepresented, but also determine the frequency and percentage of particular accident types systemwide or for specified portions of the system. This capability can be used to investigate the need for systemwide engineering improvements (e.g., shoulder rumble strips on freeways) and for enforcement and public education efforts that may be effective in situations in which engineering countermeasures are not.

SafetyAnalyst provides six tools to assist designers in trade-off analysis for site-specific alternatives.

- *Network Screening Tool*. Identify sites with potential for safety improvements.
- *Diagnosis Tool*. Diagnose the nature of safety problems at specific sites.
- *Countermeasure Selection Tool*. Select countermeasures to reduce accident frequency and severity at specific sites.
- *Economic Appraisal Tool*. Conduct an economic appraisal of a specific countermeasure or several alternative countermeasures for a specific site.
- *Priority Ranking Tool*. Rank sites and proposed improvement projects based on the benefit and cost estimates determined by the economic appraisal tool.
- *Countermeasure Evaluation Tool*. Conduct before/after evaluations of implemented safety improvements (*80*).

CHAPTER THREE

AGENCY EXPERIENCE

This chapter presents a brief summary of the results of the detailed survey. This discussion is not meant to be all-inclusive, but simply to provide an overview of the responses received regarding evaluation of trade-offs in the design selection process, risk, tools and training, agency experience, design exception process, and the future. Each STA has a unique operating environment, and this information is only a general overview of the approaches being utilized across the nation.

Appendix A and Appendix B contain the survey instrument and detailed responses, respectively. Of the 52 surveys distributed, 43 were returned from the following 41 STAs, as well as the District of Columbia and Puerto Rico:

Alabama	Kansas	Nevada	South Dakota
Arkansas	Kentucky	New Hampshire	Tennessee
California	Maine	New Jersey	Texas
Colorado	Maryland	New Mexico	Utah
Delaware	Massachusetts	New York	Vermont
Florida	Michigan	North Carolina	Virginia
Georgia	Minnesota	North Dakota	Washington
Hawaii	Mississippi	Ohio	Wyoming
Idaho	Missouri	Oregon	
Illinois	Montana	Pennsylvania	
Iowa	Nebraska	South Carolina	

Of the 43 responses, 41 STAs agreed that trade-off considerations enter into their process for geometric design decisions. These 41 STAs provided input on the remaining survey questions. Because not all questions were completed by responding STAs, in some instances there are fewer than 41 responses to a particular question.

EVALUATION OF TRADE-OFFS IN THE DESIGN SELECTION PROCESS

As CSS/CSD becomes more deeply integrated into the highway design community, more STAs are developing formalized processes to take advantage of the tools available to evaluate trade-offs in the design selection process. However, a little more than half of the responding STAs still do not have a formalized process in place, and in many instances where a formalized process does exist, it is rooted in the conventional design exception process. At the other end of the spectrum, Missouri Department of Transportation (MoDOT) has moved to a philosophy of "Practical Design" in which trade-offs become the everyday way of doing business. To support this approach, MoDOT has developed *Practical Design: Meeting Our Customers' Needs* (*81*). Other agencies such as Colorado Department of Transportation (CDOT) utilize CSS/CSD procedures for evaluating trade-offs and have developed visioning documents that outline their approach [Context Sensitive Solutions (CSS) Vision for CDOT (*82*)]. Similarly, PennDOT has developed tools to aid the consideration of community context for evaluating trade-offs through a detailed form called a Community Context Audit (*83*).

Most agencies evaluate trade-offs during either preliminary engineering or environmental clearance. However, several respondents sagely point out that trade-offs are often not raised until design is nearly completed. This would greatly reduce flexibility in being able to address the issues associated with the trade-off. One respondent cited organizational difficulties in dealing with trade-offs during the preliminary engineering phase as a result of the agency not having a predesign unit to handle these types of decisions, with the result that most decisions on design values cannot be undertaken until the design phase.

The majority of agencies point to consultant staff as the primary resource for performing the analysis of trade-offs in the design selection process. In addition, the majority of agencies have centralized control of approval authority for the supporting analyses and documentation for these trade-off decisions. Also, most agencies had different units approving the trade-off decisions and approving design exceptions.

The role of key staff within the agency was queried:

- *Chief Engineer.* Final approval on design exceptions.
- *Counsel.* Typically not involved in design trade-off decisions. May be asked for legal opinion on tort issues.
- *Design Project Manager.* Responsible for project development, assessment of risk, and documentation of trade-off decisions.
- *Engineering and Planning Specialists.* Develops and evaluates trade-offs and risk.

- *Public Information Officer.* Typically not involved in design trade-off decisions, but communicates decisions once made.

During the development of the survey, 11 typical categories of trade-offs were identified for inclusion: access management, cost, environmental issue, historic impact, human factors/driver expectancy, operational efficiency, right-of-way availability, safety, schedule, social concerns, and tort liability exposure. Agencies were asked to represent whether they included the listed trade-offs as project goals in a project P&N statement (see Table 15). With the exception of tort liability exposure, all other trade-offs were either always or sometimes included in a P&N. Not surprisingly, almost all responding STAs always include safety in the P&N. The other trade-offs that at least half of the agencies always included in a P&N were cost and environmental issues, though operational efficiency falls just below this threshold.

The agencies were also asked to identify how goals associated with these typical trade-off categories were measured—quantitatively, qualitatively, or using a combination of both (see Table 15). Cost and schedule were most often measured quantitatively. Human factors/driver expectancy and social concerns were most often measured qualitatively. All other categories were measured using a blend of both types of analysis.

The agencies were asked to rank the top three categories of trade-offs used as justification for design decisions. Overwhelmingly, the top category was safety. Both cost and environmental issue showed strongest as the second and third most often used. When all responses were tallied, it was clear that the categories of greatest concern were safety, cost, and environmental issues. Each of these categories received between 24 and 28 total responses (i.e., were selected as either the most often, second most often, or third most often used trade-off). The next most represented trade-offs are operational efficiency at 12 and ROW availability at 10. All other trade-off categories were selected five or fewer times. This clearly demonstrates that most agencies typically focus on a limited number of trade-offs during a design decision.

STAs were then asked to rank on a scale of 1 to 10 (10 being very likely) the likelihood of a particular trade-off being accepted as justification for a design decision. Average scores ranged from 5.3 to 8.1 (see Table 16). Continuing the previously identified trend, in the categories of safety, cost, and environmental issue, most respondents ranked the likelihood very high (average scores for safety 8.1, cost 7.8, and environmental issues 8.1). The trade-offs of historic impact, operational efficiency, and ROW availability also had high rankings. The rest of the trade-offs' average scores were near the middle of the range.

TABLE 16

AVERAGE SCORES FOR AGENCY RANKING OF TRADE-OFF CATEGORY AS JUSTIFICATION FOR DESIGN EXCEPTION

Trade-Off	Score
Access Management	5.8
Cost	7.8
Environmental Issue	8.1
Historic Impact	7.7
Human Factors/Driver Expectancy	6.5
Operational Efficiency	7.3
Right-of-Way Availability	6.8
Safety	8.1
Schedule	5.7
Social Concerns	5.9
Tort Liability Exposure	5.3

TABLE 15

NUMBER OF AGENCIES RESPONDING REGARDING INCLUSION OF TRADE-OFF CATEGORY AS A P&N GOAL AND MEASUREMENT METHODOLOGY EMPLOYED TO EVALUATE

	As a P&N Goal			Measurement		
	Always	Sometimes	Never	Quantitative	Qualitative	Both
Access Management	6	31	4	8	11	20
Cost	21	18	2	25	2	13
Environmental Issue	21	17	3	2	10	27
Historic Impact	16	22	3	4	14	22
Human Factors/Driver Expectancy	14	21	6	2	19	16
Operational Efficiency	20	21	0	13	5	23
Right-of-Way Availability	16	21	4	14	3	21
Safety	32	7	2	1	5	35
Schedule	12	24	5	20	4	12
Social Concerns	13	26	1	1	25	14
Tort Liability Exposure	9	19	12	2	10	19

Next, the agencies were asked to detail the methodology typically used to measure the listed trade-off. The responses have been synthesized to represent the most common received.

- *Access Management.* Expert opinion, engineering judgment, state regulation, or benefit/cost analysis.
- *Cost.* Benefit/cost analysis, cost comparison, expert opinion, or value engineering.
- *Environmental Issue.* Environmental studies, federal/state regulation, or expert opinion.
- *Historic Impact.* Federal/state regulation, environmental study, or expert opinion.
- *Human Factor/Driver Expectancy.* Expert opinion or engineering judgment.
- *Operational Efficiency.* Traffic analysis/modeling or expert opinion.
- *Right-of-Way Availability.* Benefit/cost analysis, cost comparison, expert opinion, or engineering judgment.
- *Safety.* Expert opinion, engineering judgment, or crash analysis.
- *Schedule.* Expert opinion or scheduling analysis.
- *Social Concerns.* Public/stakeholder input, expert opinion, engineering judgment, and impact matrix.
- *Tort Liability Exposure.* Expert opinion or legal counsel.

In almost all instances, STAs document design decisions (other than design exceptions) in some type of project report, file, correspondence, or meeting minutes. The trade-offs associated with these decisions often require examining the acceptable range for a particular criterion. Based on survey responses, the value selected is most often determined by using engineering judgment, expert opinion, benefit/cost analysis, or some type of value assessment.

Approximately three-quarters of the STAs responding noted that public involvement plays a role in the approval of a trade-off. However, the comments received regarding how public involvement affected the process were not consistent as to what elements of the process can be affected, at what intensity, and how often. For example, one comment stated that public involvement affects the process only if the trade-off under consideration was raised through the public involvement process, whereas another considered stakeholder input only for items that will not adversely affect safety. Other STAs utilize public input to help make decisions and even put stakeholders on the project design team. However, it was stressed that the final decision regarding a design lies with the agency. Most respondents utilize some type of public information meeting as the primary way to communicate these decisions to the public, though some agencies referenced using project websites or press releases.

The responding agencies were spilt approximately 50-50 when asked if there were any gaps, problems, or missing components in the procedures and tools associated with evaluating trade-offs. Those who believed there were gaps were concerned that although some guidelines are provided, the evaluation of trade-offs usually relies on engineering judgment. Further, evaluation of these trade-offs has become a group decision, which can result in failure to adequately identify exceptions and, thus, may not consider appropriate trade-offs. This is compounded by a lack of experienced staff, sufficient funding, and standardized documentation, as well as inconsistencies associated with informal practices at some agencies, and can be influenced by aggressive project schedules and political involvement. Finally, there is a need for more detailed protocols to deal with these trade-offs and their documentation. Those who did not believe that there were gaps pointed to processes and policies that, when followed, minimized gaps.

Building on this assessment, STAs identified strengths and weaknesses associated with their current design selection process relative to evaluation of trade-offs. For strengths, the most pervasive responses focused on the inherent flexibility in both standards and approach and on establishing complete documentation of decisions. Other comments referred to the use of CSS/CSD to develop an all-inclusive, collaborative design and decision-making process in which the design criteria are based on the context of the project area and interdisciplinary teams are utilized. For weaknesses, many comments echoed those made regarding gaps in the process—inconsistency, lack of experienced staff, lack of staff training, and lack of a clear-cut process or procedure. Other respondents noted that it can be difficult to achieve consensus on trade-offs and that analysis sometimes comes too late in the process. Finally, a concern was raised that the approach does not address a combination of decisions that meet standards, but could still result in poor design.

RISK

Agencies were asked to define acceptable risk for the use of trade-offs in the design selection process. The following is a sample of the responses:

- Acceptable risk would be defined as little to no chance the trade-off would cause an increase in the number or severity of accidents.
- Use risk matrixes and evaluate risk on a case-by-case basis.
- Most is engineering judgment or based on guidance material.
- No such formal procedures are typically used.
- There are not tools used to help define acceptable risk. Do not feel comfortable to document an "acceptable risk" on a project.

STAs were then asked to define unacceptable risk for the use of trade-offs in the design selection process. The following is a sample of the responses:

- A risk would be considered unacceptable if there is a significant impact to safety considerations.
- Reducing safety to deliver a project within the programmed cost is unacceptable.
- Unacceptable risk for this agency generally involves reducing safety on a facility (perceived or data driven) or making choices that would delay a project out of a fiscal year or would increase costs to more than 110% of budget.
- Risk is only considered informally, so we don't have a definition.
- Expert opinion is used to evaluate risk and determine unacceptable risk on a case-by-case basis by utilizing all available input and data to determine the safety and operational effects of the project.
- Risk analysis not undertaken, trade-off determined by the maximum safety and facility benefit with reasonable and available budget.
- After completing a design risk analysis and identifying strategies to minimize those risks, the residual risk can be compared with the corporate risk tolerance (for example, safety risk). If that level of residual risk cannot be tolerated, additional resources and design strategies will be necessary.

Approximately three-quarters of the agencies surveyed did not have risk prediction tools or techniques to assist in balancing competing interests in the design process. Those that did cited the use of the HSM, IHSDM, Roadside Safety Analysis Program (RSAP), VE, and crash history as tools for risk prediction. In addition, quantitative risk analysis, risk matrixes, and risk management were identified as techniques in use. Of those agencies that cited using risk prediction tools or techniques, almost all used ones that contained a mixture of both qualitative and quantitative analysis.

TOOLS AND TRAINING

Approximately one-half of the responding agencies have specific tools to assist designers in evaluating trade-offs in the design selection process. These tools include the HSM, IHSDM, RSAP, VE, crash history, life-cycle cost analysis, and Design Policy manual. Approximately half also have training to assist designers in evaluating trade-offs, including classes, workshops, and webinars on geometric design exceptions, context sensitivity, CSS, risk analysis, value analysis, risk management, roadside design, geometric design, and project management. In addition, some agencies cited mentoring as a way of passing on knowledge.

AGENCY EXPERIENCE

Only five responding agencies have developed specific performance goals regarding the evaluation of trade-offs in the design selection process:

- Crash reduction goals and right-sizing cost savings goals.
- For bridges, rehabilitation work must provide a certain life at an acceptable condition rating to justify the cost of rehabilitation.
- Make transportation networks safer, make infrastructure last longer, make organization a place that works well and make organization a great place to work.
- Reducing operating expenses and increasing infrastructure investment.
- The goals outlined in Target Zero, a strategic highway safety plan.

Agencies were also asked to provide examples of successful implementation in the design selection process:

- The US 285 Environmental Assessment project received an award for CSS. The design implemented some variations to a design based entirely on safety and mobility. This was documented in a paper presented to TRB as part of an NCHRP study currently being conducted.
- US 36 – Responded to public input relative to managed lane separation and shoulder design to reduce the project's footprint and impacts.
- 6th and Wadsworth – Trade-off on superelevation on a loop ramp to reduce ROW impacts.
- Parker/225 – Replaced flyovers with left turn lanes.
- Downtown Chaska (Trunk Highway 41, still in planning/design): Trade-offs were explored between competing cross-sectional width elements to arrive at an efficient and safe cross section and equitable balance. This included design exceptions for lane width and shoulder width. Included in the consideration was the need for a wide raised median for traffic calming and pedestrian refuge. Additionally, nonwarranted traffic signals are included in the proposal to aid in safe pedestrian crossings. This was negotiated with the local city, who agreed to make every other cross-street a right-in/right-out condition in exchange for the nonwarranted signals. This project is an example of trade-offs in competing design elements as well as functional, operational, and safety elements. Although nonwarranted signals are typically considered dubious from the standpoint of safety, overall expected safety is improved owing to the pedestrian safety improvement and the leveraged access restriction.
- I-235 project had areas of tight ROW in an urban setting. There was not enough room in one area to provide required shoulder width without purchasing massive ROW or building complex retaining walls. Interstate standards would have required a 12 ft median side shoulder in this area and there was only room for 6 ft. The shoulders were built at 8 ft. and the lanes were reduced to 11 ft. It was considered safer to have space for a car to get off so the shoulder was built at 8 ft and the lanes were narrowed to 11 ft.

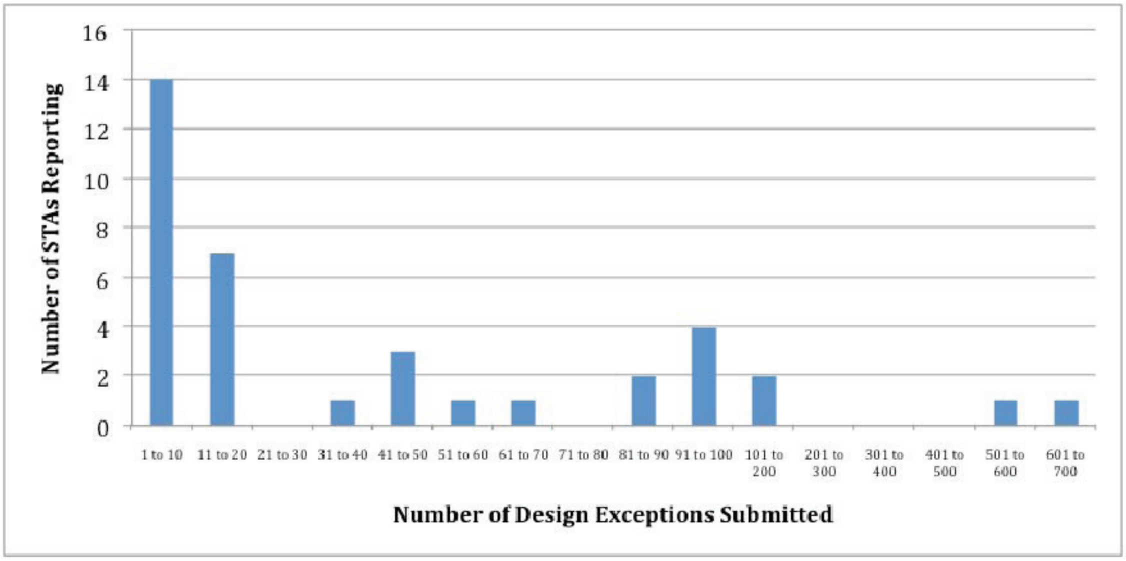


FIGURE 35 Annual number of design exceptions submitted.

- MD5 Leonardtown – Heavy movement of horse and buggy on mainline of state highway. Revised typical section of roadway to accommodate horse and buggy safely with cars.
- MoDOT has undertaken an enormous bridge replacement program on a greatly reduced budget. Some of the trade-offs involved reasonable roadside hardware considerations such as delineation-only option for bridge ends on very low-volume roads. There were hydraulic trade-offs such as small increases in upstream rise where appropriate. Deck widths were decreased, employing narrower shoulders on minor road structures. Because of these and numerous other issues, 800 bridges will be replaced or undergo major rehabilitation within 3 years at a fraction of the cost of replacing the same number, within the same time span, by conventional methods.
- On the US 95 widening project in Las Vegas from I-15 to Summerlin, we needed to add additional travel lanes, but the roadway was located in massive cut section. We couldn't achieve the shoulder on the median or outside of the travel lanes, so no shoulders were included on the project. This was allowed because it was considered an interim project until the massive project was advertised 5 years down the road. We provided a 24-hr emergency resource van for the 5 years to remove broken down vehicles quickly and to assist on accidents. We continue to have the 24-hr emergency resource van because of the positive feedback from the public.
- Point Marion Bridge Project, Bridge type selected based on environmental factors.

DESIGN EXCEPTION PROCESS

STAs were asked to report the number of design exceptions that they typically processed per year. The survey did not ask respondents to specify if these design exceptions were NHS or non-NHS projects. There was a large range in the number of exceptions processed, with a low of 1 and a high of 700 (Figure 35). The average number of exceptions processed was 74. However, this average drops to 41 once the two outlier data points above 500 are removed.

Agencies were also asked to report on the number of design exceptions that were approved in a typical year. Again, there was a large range in the number of exceptions approved, with a low of 1 and a high of 600 (Figure 36). The average number of exceptions processed was 65, but this number drops to 35 with the outliers removed.

For a little more than half of the agencies reporting, all design exceptions processed were accepted. For the remaining, the number rejected varied between 1 and 148. Thus, on average, between 6 and 10 design exceptions are rejected each year, representing about 15% of those submitted. However, the rate of rejection of design exceptions also varied greatly, between 1% and 80%.

Agencies were asked if the advent of CSS/CSD or design flexibility has increased the number of design exceptions they process in a typical year. Approximately three-quarters of the agencies that responded reported there had been no change, with a little over 15% reporting that they had increased and 10% reporting that they had decreased.

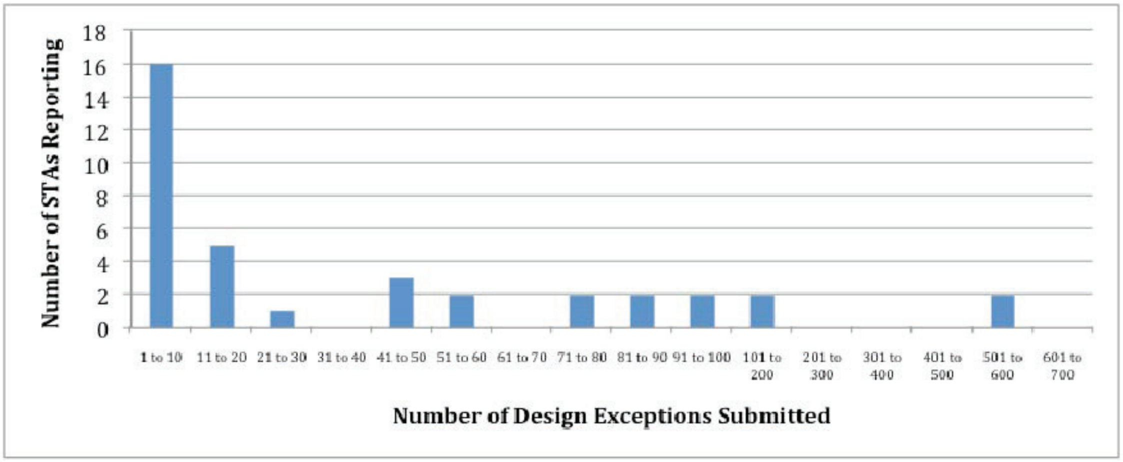


FIGURE 36 Annual number of design exceptions accepted.

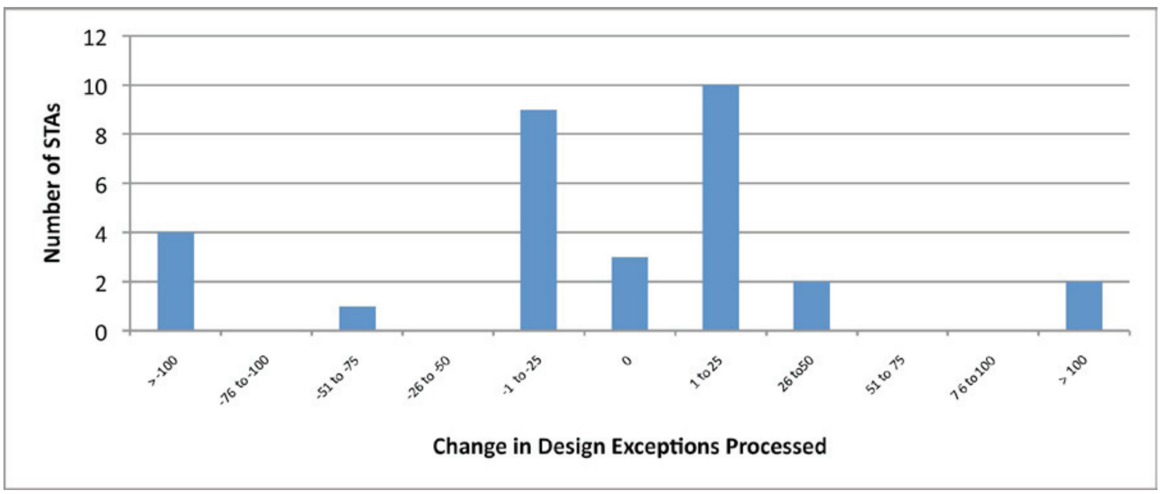


FIGURE 37 Change in design exceptions processed (2002 vs. 2010).

A previous survey conducted in 2002 as part of NCHRP Synthesis 316: Design Exception Practices (22) also determined the number of design exceptions processed in a typical year. Thirty-one of the agencies that responded to that survey also responded to this survey. As such, it was possible to compare results from the 2002 data with the 2010 data (Figure 37). By and large, the trends exhibited by this data comparison support the agencies' responses.

Agencies commented that the advent of CSS/CSD had not affected the number of design exceptions filed because the use of CSS/CSD does not always translate into design exceptions. Agencies are generally able to incorporate stakeholder input without having to deviate from accepted guidelines and practices. Other agencies reported that they had been using the principles of CSS/CSD for many years, so there was little impact from simply formalizing the process. However, one agency pointed out that FHWA rarely considers CSS/CSD as an adequate stand-alone justification for a design exception. As such, the principles of CSS/CSD are more frequently used on the state highway network in an informal way.

The responding agencies were asked to select the top three types of design exception (based on controlling criteria) for which they typically received requests. Overwhelmingly, the top criterion selected was shoulder width, which scored the highest for the greatest number of requests and overall by a wide margin in both instances. The next highest ranked criteria were horizontal alignment, vertical alignment, and lane width, which received less than half the number of responses of shoulder width. Notably, structural capacity received no responses, and additional comments provided in the survey margins stated that this criterion would never be considered.

STAs were then asked to rank on a scale of 1 to 10 (10 being very likely) how willing they typically are to consider a design exception for a particular controlling criteria. Average scores ranged from 2.0 to 7.7 (see Table 17). As determined previously, the criterion that received the greatest number of requests for design exceptions was shoulder width, which also had the highest likelihood of acceptance at 7.7. Of the other highly ranked criteria, horizontal alignment (average 5.7), vertical alignment (average 6.4), and lane width (average 6.2) also had high likelihood of design exception acceptance. In addition to these criteria, grade (average 6.1) was also highly ranked for likelihood of design exception acceptance. Structural capacity (average 2.0) was poorly ranked, confirming the comments regarding its acceptability.

TABLE 17
AVERAGE SCORES FOR AGENCY RANKING OF WILLINGNESS TO CONSIDER DESIGN EXCEPTION FOR 13 CONTROLLING CRITERIA

Design Exception	Score
Design Speed	3.9
Lane Width	6.2
Shoulder Width	7.7
Bridge Width	5.5
Structural Capacity	2.0
Horizontal Alignment	5.7
Vertical Alignment	6.4
Grade	6.1
Stopping Sight Distance	4.5
Cross Slope	5.4
Superelevation	5.5
Vertical Clearance	4.5
Horizontal Clearance	5.2

Almost all of the responding agencies stated that their criteria for new construction were the same as the AASHTO *Green Book*. However, for the controlling criterion of vertical clearance, approximately one-quarter of the responding agencies stated that the STA's criteria were greater than AASHTO's.

Agencies were then asked to relate the most common trade-offs associated with each of the controlling criteria. Those most represented are listed in order of prevalence:

- *Design Speed* – Cost, Safety, and Right-of-Way Availability.
- *Lane Width* – Right-of-Way Availability and Cost.
- *Shoulder Width* – Right-of-Way Availability, Cost, Environmental Issues, and Safety.
- *Bridge Width* – Cost, Safety, and Environmental Issue.
- *Structural Capacity* – Cost and Safety.
- *Horizontal Alignment* – Right-of-Way Availability, Safety, and Cost.
- *Vertical Alignment* – Cost, Safety, and Right-of-Way Availability.
- *Grade* – Cost, Safety, and Right-of-Way Availability.
- *Stopping Sight Distance* – Safety, Cost, and Right-of-Way Availability.
- *Cross Slope* – Safety and Cost.
- *Superelevation* – Safety and Cost.
- *Vertical Clearance* – Cost, Safety, and Operational Efficiency.
- *Horizontal Clearance* – Cost, Safety, and Right-of-Way Availability.

Next, agencies were asked to list the most common mitigation measures utilized for design exceptions of the corresponding controlling criteria:

- *Design Speed* – Signage and reduce posted speed limit.
- *Lane Width* – Signage and reduce posted speed limit.
- *Shoulder Width* – Signage, various roadside treatments (e.g., guardrail, increased clear recovery zone) and rumble strips.
- *Bridge Width* – Signage, delineators and none.
- *Structural Capacity* – Not applicable or not considered, posted weight limit and signage.
- *Horizontal Alignment* – Signage and reduce posted speed limit.
- *Vertical Alignment* – Signage and reduce posted speed limit.
- *Grade* – Signage.
- *Stopping Sight Distance* – Signage and reduce posted speed limit.
- *Cross Slope* – Signage and none.
- *Superelevation* – Signage, reduce posted speed limit and improve drainage.
- *Vertical Clearance* – Signage.
- *Horizontal Clearance* – Signage, guardrail, delineation and none.

FUTURE

Agencies were asked if there were any plans to reevaluate how they evaluate trade-offs in the design selection process in the next 6 to 12 months. Approximately three-quarters of the responding agencies stated that there were none. These agencies stated in some form that there was an adequate process in place that worked well. The comments from the one-quarter that will be considering potential changes focused on periodic reviews of all processes and updates resulting from regular reevaluation of the project development process. In addition, one agency is developing policies and recommendations for the implementation of a practical design concept. Further, agencies referenced the need to update policies and procedures for evaluating trade-offs to account for the new HSM techniques.

Agencies were then asked if there were any plans to reevaluate how the agency evaluates design exceptions in the next 6 to 12 months. Only a little over 10% of the responding agencies have plans to update these procedures. They cited a need to place more emphasis on risk and cost related to design exceptions and to incorporate training on mitigation strategies. However, most agencies responded that they had an adequate process in place.

CHAPTER FOUR

CONCLUSIONS

This synthesis is based on a literature review and survey responses from 43 agencies (41 state transportation agencies (STAs), the District of Columbia, and Puerto Rico). The literature review focused on key publications outlining the conventional approach to design as well as the newer context-sensitive solutions/context-sensitive design (CSS/CSD) and performance-based planning approaches. It also incorporated publications that outlined complimentary fields that could be used to evaluate trade-offs such as value engineering (VE), choosing by alternatives (CBA), risk analysis and management, and safety. Rather than an exhaustive literature search on a single topic area, the synthesis attempts to present an overview of the wide range of techniques available from the highway design and related fields and how they relate to trade-off analysis.

SURVEY RESULTS

One of the key issues identified by the survey was that few STAs have codified procedures for evaluating trade-offs in highway geometric design. Based on the input received, the majority of the time agencies surveyed conduct trade-off analyses they had to rely on engineering judgment.

Most agencies evaluate trade-offs during preliminary engineering or environmental clearance. However, several agencies pointed out that trade-offs often are not raised until a design is nearly complete. One of the difficulties cited that contributed to this situation was the lack of design resources and decision makers available in the predesign period of project development to undertake trade-off decisions. However, the later in the project development process that trade-off decisions are made, the more limited the flexibility in dealing with them becomes.

The majority of agencies utilize consultant staff as the primary resource for conducting trade-off analyses and have centralized approval authority for decisions regarding the outcomes. Further, different units in the agency are responsible for approving trade-offs and design exceptions.

During the development of the survey, 11 typical categories of trade-offs were identified for inclusion in the survey instrument: access management, cost, environmental issue, historic impact, human factors/driver expectancy, operational efficiency, right-of-way (ROW) availability, safety, schedule, social concerns and tort liability exposure. With the exception of tort liability exposure, agencies responded that all of these trade-offs were typically considered as goals within a Purpose and Need (P&N) statement.

Safety was overwhelmingly identified as the trade-off most used as justification for design decisions. Additionally, cost and environmental issues have a high likelihood of being used to justify design decisions. This shows that while a number of trade-offs are considered when making design decisions, agencies tend to focus on these three most often.

Continuing this trend, when asked to rank the likelihood of a trade-off being accepted as justification for a design decision, safety, cost, and environmental issues were identified as being likely to be accepted. Justifications associated with historic impact, operational efficiency, and ROW availability also were likely to be accepted.

Approximately half of the agencies believed there were gaps or missing components in the STA's procedures and tools associated with evaluation of trade-offs in design. Some of the concerns identified were associated with a concern that the lack of formal guidance and procedures forced a reliance on engineering judgment. Weaknesses of this approach are limitations associated with inexperienced staff, inconsistencies associated with informal practices, failure to adequately identify and consider appropriate trade-offs, and inconsistencies in documentation of decisions. Conversely, agencies that did not believe there were gaps often pointed to processes and policies that, when followed, minimized gaps.

Approximately three-quarters of the agencies did not have risk prediction tools or techniques to assist in balancing competing interests in the design process. Those that did have tools in place almost all used ones that combine a mixture of qualitative and quantitative analyses.

Approximately half of the agencies have some tools and training to assist designers in evaluating trade-offs in the design selection process. Common tools identified are the *Highway Safety Manual*, IHSDM, RSAP, VE, crash history, life-cycle cost analysis, and a design policy manual.

Only five agencies have developed specific performance goals regarding the evaluation of trade-offs.

Shoulder width was overwhelmingly the controlling criterion most often associated with a design exception request. Other controlling criteria typically associated with design exception requests are horizontal alignment, vertical alignment, and lane width. The controlling criterion of structural capacity was not selected by any respondent, and several respondents added notes to the survey responses that this criterion would never be considered.

When asked to rank how willing the agency typically is to consider a design exception for each of the 13 controlling criteria, shoulder width, horizontal alignment, vertical alignment and lane width were identified as likely to be considered.

Approximately three-quarters of the agencies had no plans to reevaluate how trade-offs are handled in the design selection process in the next 6 to 12 months. Further, approximately 90% of the agencies had no plans to reevaluate how design exceptions are handled over the same period.

LITERATURE REVIEW

The current edition of the *Green Book* is the basis for most of the design criteria used by STAs. The broad policy-level overview of trade-off considerations in the *Green Book* points out that the guidance is intended to provide operational efficiency, comfort, safety, and convenience for the motorist, while taking into consideration environmental quality. Further, the effects of the various environmental impacts can and should be mitigated by thoughtful design processes. However, the guidance speaks to the evaluation of trade-offs only in general terms at a fairly high level and does not provide specific cause-and-effect examples. Further, as the guidance has developed, much of the background material regarding how standards have been developed has been removed, making it more difficult for practitioners to establish these relationships.

To evaluate the trade-offs associated with design, the designer's understanding of the basic controls and criteria associated with each element of the design is important. Although the *Green Book* provides little guidance on evaluating these trade-offs, it does establish the framework from which most controls and criteria are derived.

Design criteria, established through years of practice and research, form the basis on which highway designers strive to balance competing needs for a roadway project. For many situations, there is sufficient flexibility within the design criteria to achieve a balanced design and still meet minimum values. On occasion, designers encounter situations with especially difficult site constraints, and an appropriate solution may suggest the use of design values or dimensions outside the normal range established by a control or criterion. In such cases, a design exception may be considered. Documentation of design exceptions is important to verify that sound engineering judgment and social/cultural impacts have been considered and that the proposed solution demonstrates an appropriate balance of these components.

To help overcome some of the limitations of the conventional approach to highway design as presented in the *Green Book*, FHWA produced *Flexibility in Highway Design* in 1997. The guide does not attempt to create new standards. Rather, it builds on the flexibility in the current standards to identify opportunities to use flexible design as a tool to help sustain important community interests without compromising safety.

CSS and CSD both consider the overall context within which a transportation project fits. The conventional approach to design does not emphasize an interdisciplinary approach, although the CSS/CSD approaches do. As the design process evolves, consideration given to issues that do not center on design criteria becomes increasingly important to determining the ultimate success of a design. This increases the need to identify trade-offs associated with design decisions accurately and completely and strike a balance between the competing factors in an interrelated decision-making process. Because successful projects will require a level of compromise and trade-off, CSS/CSD are excellent tools for providing structure to the process.

The concept of context-based design is closely related to CSS/CSD. However, context-based design implies that the street or road is designed to be fully compatible with its context. In context-sensitive design, in contrast, context is taken into account but is not necessarily a governing factor in the design.

Flexibility in the application of design criteria requires a fundamental understanding of the basis for these criteria (i.e., basic design controls) and the impacts of changing the dimensions of a criteria or adding/eliminating design elements. It is critical that trade-offs associated with these decisions be fully understood to preserve the integrity of the resultant design.

The analysis of trade-offs is central to the alternatives analysis process of any project. The goal of an alternatives evaluation is to provide an objective and balanced assessment of impacts, trade-offs, and benefits of each alternative. This requires careful selection of, and stakeholder agreement on, measures of effectiveness (MOEs) to be used as evaluation criteria. The MOEs need to reflect community and environmental objectives as well as transportation.

Once the alternative analysis is completed, one of the critical aspects of trade-off decisions is ensuring that adequate documentation of the decision occurs and that the documentation is retained, as both crashes and tort claims may occur many years after the decisions and construction. As important as adequate documentation is a clearly understood decision process. Projects are made up of a series of tasks, each of which may involve a series of trade-off decisions that result in a final project decision outlining the ultimate action to take. As such, it is critical that the decision process identify what decisions will be made and by whom, and what analyses, processes, and documents will be produced to support important decisions.

Several other closely related fields have insight to offer in the treatment and evaluation of trade-offs in a decision-making process and in how that process can be structured to ensure the best decisions. Many of the tools, techniques, and processes are currently utilized as part of the transportation field and can be adapted for use in trade-off analysis. Some agencies have begun to incorporate the following into everyday operations:

- Performance-based planning has most often been applied at the organizational level to assess program conformance with a stated overall transportation plan or goals and objectives. However, the process is just as applicable for evaluating trade-offs associated with alternatives, especially when put in the context of CSS/CSD. The use of outcome-based performance measures, as opposed to the traditional use of output-based performance measures, is especially apt for evaluating trade-offs.
- The VE process is a powerful decision-making process, as using the common language of functions enables an interdisciplinary team to communicate more effectively to arrive at a supportable decision. One of the challenges in using VE principles to make trade-off decisions in design is associated with the difficulty in monetizing key factors under consideration (e.g., quality of life factors).
- The CBA process assists decision makers in making informed choices on program expenditures. CBA differs from other decision-making systems in that it concentrates only on the difference between the advantages of alternatives being compared. The CBA process provides a logical, trackable linkage between the factors used to identify the preferred alternative and the major trade-offs among the alternatives considered.

Risk is perceived as the effect of uncertainty on a project or organizational objectives and represents exposure to mischance, hazards, and the possibility of adverse consequences. A risk can be acceptable for inclusion on a project when the risk is within acceptable tolerance and is balanced by a desirable benefit. As such, the principles of project risk analysis, risk and reliability analysis, and risk management may be used to support decision making regarding the trade-offs between various alternatives.

Promoting safety and safe travel is at the core of all transportation planning and design, where safety can be understood as a measure of the freedom from unacceptable risks of personal harm. The basic principles and guidelines that influence much of what happens in project development are founded on professional principles of encouraging safe design. As such, trade-offs may influence the safety potential of an alternative. Several key areas provide insight into how to address these trade-offs: the field of organizational accident analysis and prediction, safety-conscious planning, Road Safety Audits, the interactive highway safety design manual, and the new *Highway Safety Manual*.

FUTURE NEEDS

Preparation of this synthesis revealed significant needs associated with developing tools and formalized processes for dealing with trade-offs in highway geometric design. The STA survey identified several key areas that need additional research and development.

The recent release of the *Highway Safety Manual* and the commitment to continue to develop this resource to expand its coverage into additional roadway types will provide an additional resource to agencies conducting trade-off analyses that focus on safety. The ability to utilize scientific, data-based analyses to make performance-based decisions regarding the impacts of trade-offs on to safety should greatly increase designers' ability to understand the true impacts of their decisions.

VE is a useful process to ensure that the alternative selected provides the needed functions of a project at the lowest cost, while improving the quality and value of the project and reducing the overall time to complete the project. However, a number of agencies still view VE as a "check-box" activity and not as a vital tool to help ensure that trade-off analyses support the agency's vision and the project's purpose and need.

The development of risk-based methods to account for both quantitative and qualitative factors in the analysis of trade-offs is necessary to fully understand the impacts of design decisions on environmental issues.

The use of interdisciplinary teams has proven effective in areas such as Value Engineering, Road Safety Audits, and Context Sensitive Solutions/Context Sensitive Design.

Upcoming research for NCHRP 17-53, *Evaluation of the 13 Controlling Criteria for Geometric Design*, should add much-needed clarification to the safety and operational impacts of trade-offs associated with these criteria. Safety is a key rationale for all the controlling criteria except structural capacity and vertical clearance. However, the 13 controlling criteria were established at a time when safety relationships for these elements were poorly understood, and these criteria and their application have not been reconsidered as new knowledge has been gained about the relationships between geometric design elements and operations. It is hoped that this research will address questions regarding whether changes are needed in the list of design elements considered as controlling criteria and whether the list of design elements considered as controlling criteria might vary between roadway types.

One of the core principles of CSS/CSD is to ensure that all stakeholders are part of the decision-making process and feel a true sense of ownership of the outcome. This does not mean that agencies abdicate their decision-making power—the agency has the final call. However, it does ensure that the trade-off analysis is conducted in such a way as to inform all stakeholders (including the public informing the agency) of the needs and expectations of the other involved parties and the benefits and drawbacks of the many elements frequently included in transportation projects in order to gain a full understanding of the implications of the trade-off decisions. However, the results of the survey showed that three-quarters of the responding agencies did not have a role for public involvement in the approval of trade-offs.

CSS/CSD principles and practice have been developed and successfully implemented over the past two decades. The CSS/CSD principles have been accepted to varying degrees by the transportation professional community and decision makers.

Based on agency responses to the survey, consultants handle the completion of the trade-off analysis most of the time. As such, these consultants become the ultimate users of the tools and policies produced to guide trade-off considerations. The inclusion of key consultants in the development of these tools and procedures during agency development will result in a better product that can be more easily integrated into everyday practice. Just as the application of principles of CSS/CSD are successful only through the use of a interdisciplinary team that includes representatives of all key stakeholders, the same is true for the development of the tools and procedures to support CSS/CSD.

FUTURE RESEARCH

Preparation of this synthesis revealed further research needs associated with evaluation of trade-offs in highway geometric design. Several topics emerged as areas of interest for future study:

- *Tools and a Formal Process for Evaluating Trade-offs.* A number of survey respondents indicated that the approach to trade-off analysis identified a lack of formal tools, including risk prediction tools, procedures, and policies. Further research could provide a guidebook to codify tools and processes to evaluate trade-offs.
- *Online Resources for the Green Book*. The basis of many design criteria has been removed from the discussion presented in the *Green Book*, and designers are responsible for determining which design values directly support substantive safety. A successful approach for providing background materials is illustrated by Volume 4 of the 2010 *Highway Capacity Manual*, an electronic-only volume that registered users can access online. This volume features supplemental chapters on methodological details, comprehensive case studies, and a technical reference library that includes the research studies used to develop the manual. Further research could include development of a similar electronic resource to support the *Green Book*.
- *Impact of Design Consistency.* One of the tensions between the traditional *Green Book* approach and the flexible approach to roadway design associated with CSS/CSD is centered on the concept of design consistency. Further research could include a study of the safety impacts of design consistency.
- *Highway Safety Manual.* Further research to expand the number of facility types for which the HSM procedures can be used may provide designers with additional tools for considering trade-offs.
- *Integration of Project and System Level Trade-offs.* Further research could describe the relationships between project- and system level-trade-offs.

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ACRONYMS AND ABBREVIATIONS

CBA	choosing by alternatives
CDOT	Connecticut Department of Transportation
CMF	crash modification factor
CSS/CSD	context-sensitive solutions/context-sensitive design
DOT	department of transportation
FAST	Function Analysis System Technique
HFACS	Human Factors Analysis and Classification System
HSM	*Highway Safety Manual*
IHSDM	*Interactive Highway Safety Design Manual*
ISTEA	Intermodal Surface Transportation Efficiency Act
MassHighway	Massachusetts Department of Transportation
MoDOT	Missouri Department of Transportation
MOE	measure of effectiveness
NBIP	needs-based implementation plan
NEPA	National Environmental Policy Act
NHS	National Highway System
P&N	Purpose & Need
PennDOT	Pennsylvania Department of Transportation
PMI	Project Management Institute
RBS	risk breakdown structure
ROW	right of way
RSA	road safety audit
RSAP	Roadside Safety Analysis Program
SAFETEA-LU	Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users
SPF	safety performance function
STA	state transportation agency
TEA-21	Transportation Equity Act for the 21st Century
VE	value engineering
WSDOT	Washington State Department of Transportation

APPENDIX A

STA Survey Instrument

TRADE-OFF CONSIDERATIONS IN HIGHWAY GEOMETRIC DESIGN

Survey Questionnaire
NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
Project 2-05, Synthesis Topic 40-07
Trade-off Considerations in Highway Geometric Design

Current highway geometric design processes require establishment of fundamental design controls and selection of design criteria. The process then becomes dimensionally-based, with ranges in design values derived from tables, charts, and equations. However, projects also need to meet performance goals, such as those defined in the purpose and need or stakeholder goals. ***The primary purpose of this questionnaire is to identify how this trade-off between competing interests is achieved. A secondary goal of this questionnaire is to identify gaps in information and/or analysis processes available to support the design decision.***

Responses to the questionnaire will be confidential and results will be presented without affiliation.

If your STA has a formal process or procedure for evaluating trade-offs in the design selection process, we request that you forward copies of your current policies, procedures, related standards, sample of pertinent published materials, and website addresses. Please forward supporting documents to:

Paul W. Dorothy, PhD, PE, AICP
White Star Engineering Consultants
179 Kenbrook Drive
Worthington, OH 43085

If your STA does not have a formal process or procedure for evaluating trade-offs in the design selection process, but does have key documents that are used in an informal process that you feel may be helpful in illustrating how trade-offs in the design selection process are made by your STA, please forward this documentation as well.

If you have any questions, please feel free to contact Paul Dorothy at (614) 580-6202 or e-mail paulwdorothy@gmail.com.

Terminology

To improve communications, the following terms are used as defined below in conjunction with this questionnaire:

Risk: Risk is the possibility of an event occurring that will have an impact on the achievement of design, project, or agency objectives.

Context-Sensitive Solutions (CSS): CSS is a collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic, and environmental resources, while maintaining safety and mobility. CSS is an approach that considers the total context within which a transportation improvement project will exist. CSS principles include the employment of early, continuous, and meaningful involvement of the public and all stakeholders throughout the project development process. CSS may also be referred to as Context-Sensitive Design or Design Flexibility.

Design Exception: The process and resulting documentation associated with geometric features or perpetuated by highway construction projects that do not conform to the minimum criteria set forth in the standards and policies. This includes what some may refer to as design exemptions or design variance.

Controlling Criteria: The 13 elements identified by FHWA in the Federal-aid Policy Guide as requiring design exceptions. They are:

- Design speed
- Lane width
- Shoulder width

- Bridge width
- Structural capacity
- Horizontal alignment
- Vertical alignment
- Grade
- Stopping sight distance
- Cross slope
- Superelevation
- Vertical clearance
- Horizontal clearance (other than clear zone)

Below, please provide the name and associated information of the person completing this questionnaire and, if different, someone else that may be contacted for follow-up questions:

Person completing survey: ______________________________

Contact for follow-up questions (if different): ______________________________

Title: ______________________________

Agency: ______________________________

Street address: ______________________________

City: ______________________________

State: ______________________________

Zip: ______________________________

Telephone: ______________________________

Email: ______________________________

Overview Question

1. Do trade-off considerations ever enter into the process for geometric design decisions at your STA?

If you answered "no," please proceed to the final page of the survey and submit your results and thank you for your participation. If you answered "yes," please continue with the remainder of the survey.

☐ Yes

☐ No

Evaluation of Trade-offs in the Design Selection Process

This first set of questions will help us understand what trade-offs your agency considers and how it incorporates this evaluation into the overall design process.

2. Does your STA have a formal or informal process/procedure for evaluating trade-offs in the design selection process?

☐ Formal

☐ Informal

Please explain the process/procedure.

____

____

3. Please indicate on the discrete scale below where in the project development process trade-offs in the design selection process are typically evaluated. If trade-offs are evaluated at two distinctly different stages of your agency's project development process, please indicate both of these locations on the scale.

☐ 0%—Project Initiation

☐ 20%—Preliminary Engineering

☐ 40 to 60%—Environmental Clearance

☐ 80%—Final Design

☐ 100%—Plans, Specifications, and Estimates

Please provide comments.

____

____

____

4. For consultant design projects, who is responsible for performing the analysis of the trade-offs in the design selection process?

☐ Consultant Staff

☐ Agency Staff

5. Once the supporting analyses and documentation regarding trade-offs in the design selection process is complete, is the approval authority for the trade-off within the STA centralized or decentralized (e.g., district office or region)?

☐ Centralized

☐ Decentralized

6. In your STA, does the same unit responsible for approving a trade-off in the design selection process (e.g. Regional Design) also approve design exceptions or does a different unit (e.g., Chief Engineer) approve them?

☐ Same

☐ Different

7. Please identify the role and responsibilities that each of the identified positions has in your STA. Examples have been provided for each.

Chief Engineer ____

Example Role/Responsibility:

Final design exception approval.

Counsel ____

Example Role/Responsibility: Checks exception documentation and evaluates risk determination.

Design PM ____

Example Role/Responsibility: Documentation, values risk.

Engineering and Planning Specialists ____

Example Role/Responsibility: Develop and evaluate trade-offs and risk during preliminary design and environmental review stages.

Public Information Officer ____

Example Role/Responsibility: Identifies community requirements for trade-offs, organizes communication of risk and trade-offs.

8. When developing project Purpose and Need goals, does your agency typically consider the listed trade-offs as project goals? For each listed trade-off, please select if the trade-off is always, sometimes, or never utilized as a

Purpose and Need goal. Also, please select if the measurement of that goal is typically quantitative, qualitative, or both.

	As a P&N Goal			Measurement		
	Always	Sometimes	Never	Quantitative	Qualitative	Both
Access Management	❍	❍	❍	❍	❍	❍
Cost	❍	❍	❍	❍	❍	❍
Environmental Issue	❍	❍	❍	❍	❍	❍
Historic Impact	❍	❍	❍	❍	❍	❍
Human Factors/Driver Expectancy	❍	❍	❍	❍	❍	❍
Operational Efficiency	❍	❍	❍	❍	❍	❍
Right-of-Way Availability	❍	❍	❍	❍	❍	❍
Safety	❍	❍	❍	❍	❍	❍
Schedule	❍	❍	❍	❍	❍	❍
Social Concerns	❍	❍	❍	❍	❍	❍
Tort Liability Exposure	❍	❍	❍	❍	❍	❍

9. What type of trade-off is most typically used as a justification for a design decision? Please rank the top 3 by indicating which trade-off is used most often as 1, second as 2, and third as 3.

Access Management ______________________________

Cost ______________________________

Environmental Issue ______________________________

Historic Impact ______________________________

Human Factor/Driver Expectancy ______________________________

Operational Efficiency ______________________________

Right-of-Way Availability ______________________________

Safety ______________________________

Schedule ______________________________

Social Concerns ______________________________

Tort Liability Exposure ______________________________

10. Please indicate on a scale of 1 to 10 how likely your agency is to consider a listed trade-off as a reason for accepting a design decision, with 10 being very likely and 1 being not likely.

Access Management

☐ Not Likely 1

☐ 2

☐ 3

☐ 4

☐ 5

☐ 6

☐ 7

☐ 8

☐ 9

☐ 10 Very Likely

Cost

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Environmental Issue

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Historic Impact

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Human Factors/Driver Expectancy

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Operational Efficiency

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Right-of-Way Availability

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Safety

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Schedule

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Social Concerns

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Tort Liability Concerns

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

11. What methodology, if any, is typically utilized to measure each of the listed trade-offs? For example, methodologies might include expert opinion, state regulation, IHSDM, benefit/cost analysis, etc.

Access Management

____

Cost

____

Environmental Issue

____

Historic Impact

____

Human Factors/Driver Expectancy

____

Operational Efficiency

____

Right-of-Way Availability

____

Safety

____

Schedule

____

Social Concerns

____

Tort Liability Exposure

____

12. How does your agency document design decisions (beyond design exceptions)?

____
____
____

13. In instances where a range of values may be acceptable for design purposes, how does your agency determine what value will be utilized for design purposes?

____
____
____

14. Does public involvement play a role in the approval process for a trade-off in the design selection process?

☐ Yes

☐ No

If yes, please explain how PI impacts the process.

____
____
____

15. How do you communicate the results of design decisions that have been made based on trade-offs in the design selection process to the general public?

____
____
____

16. Are there any gaps, problems, or missing components in your STA's procedures and tools associated with the design selection process relative to evaluating trade-offs?

☐ Yes

☐ No

Please explain:

____

____

____

17. What strengths or weaknesses exist in your STA's current design selection process relative to evaluating trade-offs?

Strengths:

____

____

____

Weaknesses:

____

____

____

Risk

The next set of questions will help us understand how your STA views risk in the design selection process and what tools are available to measure this risk.

18. Please define acceptable risk with regards to the use of trade-offs in the design selection process for a typical project.

For example, acceptable risk might be defined using a risk matrix as a condition where the likelihood of an event occurring is improbable and the severity of the consequences is minimal. As a result, loss of life as a result of hazards on the facility is unlikely.

____

____

____

19. Please define unacceptable risk with regards to the use of trade-offs in the design selection process for a typical project.

For example, unacceptable risk might be defined using a risk matrix as a condition where the likelihood of an event occurring is frequent and the severity of the consequences is critical. As a result, design decisions that may result in schedule creep, which could lead to budget creep, are deemed unacceptable.

____

____

____

20. Does your STA have risk prediction tools or techniques to assist in balancing competing interests as part of the design process?

☐ Yes

☐ No

If yes, please describe the tool/technique and how it fits into the project development process.

____

____

____

21. If your STA does have risk prediction tools or techniques, are they

☐ Quantitative

☐ Qualitative

☐ Both

Tools and Training

This set of questions will help us understand what existing tools and training your agency has available to evaluate trade-offs in the design selection process.

22. Does your STA have any specific tools to assist designers in evaluating trade-offs in the design selection process?

☐ Yes

☐ No

If yes, please describe the tools available.

____

____

____

23. Does your STA have any training to assist designers in evaluating trade-offs in the design selection process?

☐ Yes

☐ No

If yes, please describe the training available.

____

____

____

Your Experience

This set of questions will help us understand your agency's specific project experience in implementing trade-offs in the design selection process.

24. Has your agency developed any specific performance goals regarding the evaluation of trade-offs in the design selection process?

☐ Yes

☐ No

If yes, please provide the goals developed.

____

____

____

25. Can you provide an example(s) of successful implementation of trade-offs in the design selection process?

____

____

____

Would you be willing to allow this project to be used as a potential case study for the synthesis, which would require identifying your agency affiliation with the case study results only?

- ☐ Yes
- ☐ No

Design Exception Process

This set of questions is an extension of the work that was performed as part of NCHRP Synthesis 316—Design Exception Practices, which was undertaken in 2002. It will help us understand aspects of your agency's design exception process.

26. How many design exceptions does your agency process in a typical year?

Annual number of design exceptions____

27. How many of these design exceptions are approved in a typical year?

Number of approved design exceptions _______________________________________

28. Has the advent of context-sensitive design, context-sensitive solutions, or design flexibility increased the number of design exceptions processed by your agency in a typical year?

- ☐ Increased
- ☐ Decreased
- ☐ No change

Please explain.

____

____

____

29. For which type of design exceptions do you typically receive the most requests? Please rank the top 3 by indicating the greatest number of requests as 1, second as 2, and third as 3.

Design Speed __________________________________

Lane Width __________________________________

Shoulder Width __________________________________

Bridge Width __________________________________

Structural Capacity __________________________________

Horizontal Alignment __________________________________

Vertical Alignment __________________________________

Grade __________________________________

Stopping Sight Distance __________________________________

Cross Slope __________________________________

Superelevation ____

Vertical Clearance ____

Horizontal Clearance ____

30. Please indicate on a scale of 1 to 10 how willing your agency typically is to consider a design exception for a particular controlling criteria, with 10 being very likely to consider a design exception for the listed criteria and 1 being not likely to consider a design exception for the listed criteria.

Design Speed

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Lane Width

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Shoulder Width

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Bridge Width

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Structural Capacity

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Horizontal Alignment

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Vertical Alignment

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Grade

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Stopping Sight Distance

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Cross Slope

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Superelevation

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Vertical Clearance

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

Horizontal Clearance

- ☐ Not Likely 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10 Very Likely

31. For each of the controlling criteria listed, is your STA's criteria for new construction and reconstruction higher than AASHTO's (check one for each)?

	STA Criteria Greater Than AASHTO	STA Criteria The Same as AASHTO
Design Speed	❍	❍
Lane Width	❍	❍
Shoulder Width	❍	❍
Bridge Width	❍	❍
Structural Capacity	❍	❍
Horizontal Alignment	❍	❍
Vertical Alignment	❍	❍
Grade	❍	❍
Stopping Sight Distance	❍	❍
Cross Slope	❍	❍
Superelevation	❍	❍
Vertical Clearance	❍	❍
Horizontal Clearance	❍	❍

32. Please select the most common and next most common trade-offs associated with a design exception for the corresponding criteria:

Design Speed

Access Management ____________________

Cost ____________________

Environmental Issue ____________________

Historic Impact ____________________

Human Factors/Driver Expectancy ____________________

Operational Efficiency ____________________

Right-of-Way Availability ____________________

Safety ____________________

Schedule ____________________

Social Concerns ____________________

Tort Liability Exposure ____________________

Lane Width

Access Management ____________________

Cost ____________________

Environmental Issue ____________________

Historic Impact ____________________

Human Factors/Driver Expectancy ____________________

Operational Efficiency ____________________

Right-of-Way Availability ____________________

Safety ____________________

Schedule ____________________

Social Concerns ____

Tort Liability Exposure ____

Shoulder Width

Access Management____

Cost____

Environmental Issue____

Historic Impact____

Human Factors/Driver Expectancy ______________________________

Operational Efficiency ____

Right-of-Way Availability ______________________________________

Safety ____

Schedule ____

Social Concerns ____

Tort Liability Exposure ____

Bridge Width

Access Management____

Cost____

Environmental Issue____

Historic Impact____

Human Factors/Driver Expectancy ______________________________

Operational Efficiency ____

Right-of-Way Availability ______________________________________

Safety ____

Schedule ____

Social Concerns ____

Tort Liability Exposure ____

Structural Capacity

Access Management____

Cost____

Environmental Issue____

Historic Impact____

Human Factors/Driver Expectancy ______________________________

Operational Efficiency ____

Right-of-Way Availability ______________________________________

Safety ____

Schedule ____

Social Concerns ____

Tort Liability Exposure ____

Horizontal Alignment

Access Management____________________

Cost____________________

Environmental Issue____________________

Historic Impact____________________

Human Factors/Driver Expectancy ____________________

Operational Efficiency ____________________

Right-of-Way Availability ____________________

Safety ____________________

Schedule ____________________

Social Concerns ____________________

Tort Liability Exposure ____________________

Vertical Alignment

Access Management____________________

Cost____________________

Environmental Issue____________________

Historic Impact____________________

Human Factors/Driver Expectancy ____________________

Operational Efficiency ____________________

Right-of-Way Availability ____________________

Safety ____________________

Schedule ____________________

Social Concerns ____________________

Tort Liability Exposure ____________________

Grade

Access Management____________________

Cost____________________

Environmental Issue____________________

Historic Impact____________________

Human Factors/Driver Expectancy ____________________

Operational Efficiency ____________________

Right-of-Way Availability ____________________

Safety ____________________

Schedule ____________________

Social Concerns ____________________

Tort Liability Exposure ____________________

Stopping Sight Distance

Access Management____________________

Cost____________________

Environmental Issue ____

Historic Impact ____

Human Factors/Driver Expectancy __________________________________

Operational Efficiency ____

Right-of-Way Availability ____

Safety ____

Schedule ____

Social Concerns ____

Tort Liability Exposure ____

Cross Slope

Access Management ____

Cost ____

Environmental Issue ____

Historic Impact ____

Human Factors/Driver Expectancy __________________________________

Operational Efficiency ____

Right-of-Way Availability ____

Safety ____

Schedule ____

Social Concerns ____

Tort Liability Exposure ____

Superelevation

Access Management ____

Cost ____

Environmental Issue ____

Historic Impact ____

Human Factors/Driver Expectancy __________________________________

Operational Efficiency ____

Right-of-Way Availability ____

Safety ____

Schedule ____

Social Concerns ____

Tort Liability Exposure ____

Vertical Clearance

Access Management ____

Cost ____

Environmental Issue ____

Historic Impact ____

Human Factors/Driver Expectancy __________________________________

Operational Efficiency ______________________________

Right-of-Way Availability ______________________________

Safety ______________________________

Schedule ______________________________

Social Concerns ______________________________

Tort Liability Exposure ______________________________

Horizontal Clearance

Access Management______________________________

Cost______________________________

Environmental Issue______________________________

Historic Impact______________________________

Human Factors/Driver Expectancy ______________________________

Operational Efficiency ______________________________

Right-of-Way Availability ______________________________

Safety ______________________________

Schedule ______________________________

Social Concerns ______________________________

Tort Liability Exposure ______________________________

33. Please list the most common mitigation measures utilized for design exceptions of the corresponding criteria. Does the listed mitigation measure make it more likely, equally likely, or less likely that a design exception would be accepted?

Design Speed

Most Common Mitigation Measure

____

Mitigation Measure Impact on Acceptance of Design Exception

☐ More Likely

☐ Equally Likely

☐ Less Likely

Lane Width

Most Common Mitigation Measure

____

Mitigation Measure Impact on Acceptance of Design Exception

☐ More Likely

☐ Equally Likely

☐ Less Likely

Shoulder Width

Most Common Mitigation Measure

____

Mitigation Measure Impact on Acceptance of Design Exception

- ☐ More Likely
- ☐ Equally Likely
- ☐ Less Likely

Bridge Width

Most Common Mitigation Measure

____

Mitigation Measure Impact on Acceptance of Design Exception

- ☐ More Likely
- ☐ Equally Likely
- ☐ Less Likely

Structural Capacity

Most Common Mitigation Measure

____

Mitigation Measure Impact on Acceptance of Design Exception

- ☐ More Likely
- ☐ Equally Likely
- ☐ Less Likely

Horizontal Alignment

Most Common Mitigation Measure

____

Mitigation Measure Impact on Acceptance of Design Exception

- ☐ More Likely
- ☐ Equally Likely
- ☐ Less Likely

Vertical Alignment

Most Common Mitigation Measure

____

Mitigation Measure Impact on Acceptance of Design Exception

- ☐ More Likely
- ☐ Equally Likely
- ☐ Less Likely

Grade

Most Common Mitigation Measure

____

Mitigation Measure Impact on Acceptance of Design Exception

- ☐ More Likely
- ☐ Equally Likely
- ☐ Less Likely

Stopping Sight Distance

Most Common Mitigation Measure

____

Mitigation Measure Impact on Acceptance of Design Exception

☐ More Likely

☐ Equally Likely

☐ Less Likely

Cross Slope

Most Common Mitigation Measure

____

Mitigation Measure Impact on Acceptance of Design Exception

☐ More Likely

☐ Equally Likely

☐ Less Likely

Superelevation

Most Common Mitigation Measure

____

Mitigation Measure Impact on Acceptance of Design Exception

☐ More Likely

☐ Equally Likely

☐ Less Likely

Vertical Clearance

Most Common Mitigation Measure

____

Mitigation Measure Impact on Acceptance of Design Exception

☐ More Likely

☐ Equally Likely

☐ Less Likely

Horizontal Clearance

Most Common Mitigation Measure

____

Mitigation Measure Impact on Acceptance of Design Exception

☐ More Likely

☐ Equally Likely

☐ Less Likely

Future

34. Are there any plans to reevaluate how your agency evaluates trade-offs in the design selection process in the next 6 to 12 months?

☐ Yes

☐ No

Please explain what potential changes may be considered or why no change is planned.

____

____

____

35. Are there any plans to reevaluate how your agency evaluates design exceptions in the next 6 to 12 months?

☐ Yes

☐ No

Please explain what potential changes may be considered or why no change is planned.

____

____

____

Summary

36. We are interested in any further comments that you may have with regards to how your agency deals with risk in the design selection process when evaluating trade-off considerations in highway geometric design.

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Thank you for your time and input!

Paul Dorothy

APPENDIX B
Summary of STA Survey Responses

Overview Question

1. Do trade-off considerations ever enter into the process for geometric design decisions at your STA?

If you answered "no," please proceed to the final page of the survey and submit your results and thank you for your participation. If you answered "yes," please continue with the remainder of the survey.

42 Yes

2 No

Evaluation of Trade-offs in the Design Selection Process

This first set of questions will help us understand what trade-offs your agency considers and how it incorporates this evaluation into the overall design process.

2. Does your STA have a formal or informal process/procedure for evaluating trade-offs in the design selection process?

15 Formal

22 Informal

4 Both

Please explain the process/procedure.

- A "Design Variance" process is followed if there is a violation of GDOT Standards. This process is almost identical to the design exception process, although it does not require review/approval from FHWA. If a design violates a design recommendation or guidance, the decision will need to be documented in the project's design data book.
- A design exception fact sheet is prepared to document non-standard features.
- A design exception would be required for any of the 13 controlling criteria. Any other trade-offs in the design standards would be more informal and are covered by a memo to the project file describing the circumstances, design standards, associated impacts and reasoning as to why the ultimate decision was made.
- As a professional engineer, each designer evaluates the trade-offs of this proposed design or alternative and discusses it with the design area Director.
- Both formal and informal. Our formal project development process utilizes a multi-disciplinary scoping team that evaluates candidate projects to determine the most appropriate design solution. The multi-disciplinary scoping team coordinates informally throughout the project's development to create a final design that has incorporated input from shareholders.
- Case by case evaluation
- Certain items such as environmental impacts, as costs are required to be evaluated for each alternative, and the comparison is required to be shown in the design approval document.
- Currently, unless specifically designated as a "livable community," the process is informal. Design criteria for livable communities are contained in Chapter 21 of our Plans Preparation Manual (PM). If the project is not in such a community, deviations from AASHTO minimum criteria (for the 13 controlling elements) are documented as Exceptions and deviations to state criteria are documented as "Variations." The latter do not require the same level of documentation as the former. We are currently investigating incorporating the AASHTO *Highway Safety Manual* into the decision making process.
- Decide at the local district level as long as within design parameters.
- Depends on the trade off. It may involve a simple cost comparison or it may involve other analyses such as traffic analysis, alternate design, Right-of-Way constraints, etc.
- Depends on the trade off. It may involve a simple cost comparison or it may involve other analyses such as traffic analysis, alternative design, etc.
- Designers are encouraged to provide flexibly in roadway design and to identify situations where 'typical' design guidelines/standards cannot be met. The AASHTO *Green Book* and VDOT *Road Design Manual* provide guidance on evaluating design criteria and providing background as to how the design values were established. It is then the responsibility of the designer to study the issue, provide alternatives based upon project needs/concerns and to make sound engineering decisions. Decisions must be documented in the project file.

- Deviations are handled at the regional level requiring only the Region Preconstruction Engineer's signature. Both design exceptions and waivers require the design exception form be filled out completely with supporting information as needed. The form is signed by region personnel and submitted to Statewide Traffic and Preconstruction Engineers for review and approval.
- During the Planning Phase of our major capital projects SHA follows the NEPA process to address environmental, socio-economic, historical, public opinion, and many other factors that were used for design selection.
- Each situation is evaluated with available objective information and supplemented with subjective information.
- In most cases, the issues are resolved with all the stakeholders at our initial reconnaissance inspection. With more complex issues, a special study, life cycle cost analysis, etc. might be done before the final scope of work can be determined. On projects with much public impact, one or more public meetings are held to collect public input before finalizing the scope. The District Engineers have the most influence on the final scope of work.
- Indiana department of transportation has established processes to evaluate and approve exceptions to designs which do not conform to the minimum criteria as set forth in the Indiana Design Manuals, Standards, Policies and Standard Specifications. Please refer to the attached PDF for further details on these procedures.
- MoDOT handles trade-offs a bit differently than most STAs. Since adopting the business philosophy of Practical Design some five years ago, trade-offs have become the everyday way of doing business. The design standards reflect this practice as well. The formal process enters in when even the new standards cannot be met or when there is an opportunity to add additional value to the project. At that point, a design exception is sought according to the following process. When the need for a design exception has been identified, the appropriate person (listed below) is responsible for completing the standard Design Exception Information Form. Use of this form is more effective official documentation than a casual notation. The form must include a detailed description of the rationale for the change. After completion of the form, the order of approval by the transportation officials, for each project category, is given below. A copy of every design exception is provided to the Design Division for the permanent project file. A copy of the form is also kept in the district file. Full FHWA Oversight Projects 1. district project manager 2. district engineer 3. State Design and/or State Bridge Engineer. FHWA Exempt Roadway Projects 1. district project manager 2. district engineer 3. State Bridge Engineer. Consultant Designed or Cost Share Projects 1. consultant or local public agency 2. appropriate project-specific path show above.
- Options are reviewed during the scoping and design process on a case by case basis with cost, environmental, social, utility, and safety reviewed and analyzed.
- Oregon uses Project Delivery Teams (PDT). The PDT's are multi-disciplined with some members added from stakeholder groups.
- Please refer to the attached Context Sensitive Solutions (CSS) Vision for CDOT.pdf for policy guidelines for evaluating trade-offs at the Colorado Department of Transportation. Formal process/procedure for evaluating trade-offs in Design Decisions and Design Variances includes some form of Benefit/Cost analysis that would explicitly consider environmental and safety impacts. CDOT closely adhere to the Environmental Stewardship Guide which applies fundamental National Environmental Policy Act, NEPA, policy and principles to guide procedures and the decision-making process. Informal process/procedures for evaluating trade-offs includes the involvement of all Stakeholders and following the guidelines defined in Context Sensitive Solutions (CSS) Vision for CDOT.pdf then exercising engineering judgment in balancing trade-offs. CDOT holds Open Houses, Public Meetings, Scoping Meetings, Field Inspection Review Meetings and Final Office Review Meetings to solicit comments and recommendations for trade-offs. Informal processes for environmental issues. Generally environmental issues do not elicit change in the design process of a project unless for regulatory requirements. Some high profile (large, mountain corridors, etc.) are the exception.
- Project Manager and Project Development Team decide project specifics. Details are captured in official meeting minutes. Design exceptions are documented and approved by Central Office.
- Teams scope projects to determine design criteria based on specific circumstances of each project. Design criteria are context-based in accordance with PennDOT's *Smart Transportation Guidebook*.
- The designer is responsible for considering all of the trade-offs and then reviewing this with management for consistency and appropriateness. The sections 1C-1 and 1C-8 of our Design Manual work together to describe the process. They are available here: http://www.iowadot.gov/design/manual/manual.html?reload
- The formal process is the formal design exception process for the 13 critical design elements. Otherwise, informal evaluation and documentation processes are used for informal design exceptions (general design elements) and all other tradeoffs in the design process.
- The process would depend on the element under scrutiny. For example, some the traffic type decisions the engineering process could include HCM operational analyses or just engineering judgment based on experience. For more complex multidisciplinary decisions planning reports are typically prepared and circulated for review and comment.
- The State has a standard process outlined within the design manual for project developments. The project developments process incorporates documentation for the design decisions made on a project. The design manual can be found at the following web link -- http://itd.idaho.gov/manuals/Online_Manuals/Design/Design_Manual.htm
- The steps are formal, but the evaluation method may change from project to project.

- There is no such process. Tradeoffs, as they are called in this study, are done as part of the normal design of each project -- as they have been done for decades.
- This is a difficult question to answer as we have a design exception process for formal deviations from our state standards, however, we have an informal process for evaluation within the standard ranges.
- Trade-offs are based on an analysis of crashes related to geometric elements at site specific locations and what safety improvements can be attained to address crashes within a realistic budget.
- Trade-offs are considered on a project by project basis.
- Type of work is established as part of the planning and design process. Decisions are made based on policy, budget and environmental commitments.
- Typically design tradeoffs are documented by design exceptions. For design issues not involving the 13 controlling criteria, the decisions may be documented in the project file or environmental documentation.
- We do have a formal design exception process. However, most trade-offs in the design process are done on an informal basis. The informal process closely follows the formal process as far as the evaluation of design features, driver safety, environmental and right-of-way impacts and project costs.
- We follow the design exceptions procedure.
- We have both a formal and informal process depending on the tradeoff. In deviations there is a formal evaluation done to optimize the tradeoffs being considered. We use the informal process continuously through the design phase of a project.
- We look at the design and controls and determine if there needs to be a trade-off from the recommended values in the *Green Book*.

3. Please indicate on the discrete scale below where in the project development process trade-offs in the design selection process are typically evaluated. If trade-offs are evaluated at two distinctly different stages of your agency's project development process, please indicate both of these locations on the scale.

7 0% -- Project Initiation

34 20% -- Preliminary Engineering

20 40 to 60% -- Environmental Clearance

12 80% -- Final Design

4 100% -- Plans, Specifications, and Estimates

Please provide comments.

- Although we would prefer for all these things to be worked out during the concepting, it is usually left for our design engineers to take care of. The Design Manual sections I sent are targeted toward the design engineers.
- As described in 1, we usually resolve the scope of work in the reconnaissance phase, which is preceded by a Programming Study Report.
- As project progresses issues may arise that require trade-offs
- Can be done anytime through the projects but typically up to the Environmental Clearance stage.
- CDOT's philosophy is to address these trade-offs as early as possible. However, most of the comments and recommendations that CDOT designers have to respond to occur during the environmental clearance and final Design process.
- Consideration of design issues and tradeoffs is encouraged at every stage of the design process.
- Design criteria is evaluated the scoping at a field view which occurs at the beginning of Preliminary Engineering.
- Design decisions for complex, typically urban, projects may take place more towards the Preliminary Engineering phase. Otherwise, they typically happen later prior to Stage 1 plans, including submission of design exceptions.
- Design issues are typically encountered during the initial project development; however it is also common to identify issues later on in the development of the project.
- Ideally, this is covered in the Preliminary engineering phase, but it may be addressed in other phases as well if necessary.
- Mainly this kind of detail would be worked out early; however, we have had projects revised in later stages.
- Most of our design deviations are identified in our preliminary design phase which includes consideration of environmental impacts.
- Project Initiation or "Scoping Phase" attempts to address trade-offs in order to target any needed safety improvements when establishing the project budget.
- The first evaluation occurs early in the design process. It involves an assessment of the terrain -- construction costs, potential utility and right-of-way impacts and their associated costs within the context of a project's scope. The second evaluation is done when we have accurate information on the environmental resources that could be impacted by the project. Certain resources command a much higher degree of compromise.

- The goal is to add value to the projects during all phases of the project development. Design decisions are preferably handled in the earlier stages of project development, but can be incorporated in the later stages as well.
- The trade-off are usually considered at the Preliminary Engineering and at the Preliminary Field check when the project is between 20% to 60% complete and a general consensus from all the participants involved with the development of the project define such a need and or alternative in order to accommodate for a particular trade-off. Also, in respect to a project pay item unit price fluctuations from time to time, the variance in the total cost can mandate such trade-offs for adjustments to the total project cost.
- There is a formal Design Acceptance Package (DAP) milestone that contains all of the trade-offs.
- This applies only to formal design exceptions. Practical Design occurs throughout all paths of the project's life.
- This happens primarily in preliminary design, which included the environmental clearance process.
- This is when it SHOULD occur, but oftentimes we do not see Exceptions until 80-100%
- Tradeoff analysis can and is completed at all milestones of a project.
- Tradeoffs can be evaluated throughout the process as issues arise.
- We have 2 stages of the design process where we evaluate tradeoffs. During the planning/design transition, office of planning reviews design package prior to transferring to design to ensure trade-offs have been considered. During the design/construction transition, design ensures that trade-offs have been considered.
- We usually get a written Conceptual Approval from FHWA just around our 30% to make sure that they are okay with what we will continue through the NEPA process with. Then after the 60% closer to final design we will get the Final Approval.
- We would ideally like to evaluate trade-offs in the Preliminary Engineering stage, but our DOT does not have a pre-design unit so much of the decisions on design values are conducted during the Design phase.
- When the municipalities propose a highway project there is a selection committee in charge of evaluating highway and transportation needs and they decide if the petition is design worthy then, as the design of the highway project develops, trade-offs are analyzed to reduce cost and reach the project goals.

4. For consultant design projects, who is responsible for performing the analysis of the trade-offs in the design selection process?

25 Consultant Staff

10 Agency Staff

7 Both

5. Once the supporting analyses and documentation regarding trade-offs in the design selection process is complete, is the approval authority for the trade-off within the STA centralized or decentralized (e.g., district office or region)?

22 Centralized

14 Decentralized

6 Both

6. In your STA, does the same unit responsible for approving a trade-off in the design selection process (e.g., Regional Design) also approve design exceptions or does a different unit (e.g., Chief Engineer) approve them?

14 Same

22 Different

5 Both

7. Please identify the role and responsibilities that each of the identified positions has in your STA.

Chief Engineer

- Approval authority for exceptions
- Approves a Design Exception
- Approves all final plans prior to being advertised.
- Approves Scope Statement and any Amended Scope Statements
- Approves the Standard Drawings by his signature and over sights the general activities in the agency.
- Chief Engineer--Final design exception approval

- Deputy Chief Engineer grants some design approvals, and approves design exceptions for those same projects.
- Design exception approval
- Design Exception approval
- Design exception approval has delegated to District Engineers
- Design exception approval. May have to approve other trade-offs.
- Design Exception approval. Trade-offs are included as mitigation
- Design Exceptions at any time in the design process. This includes any design exceptions that fall outside the normal 13 elements, such as ADA, Plantmix Dikes, etc.
- Director of Preconstruction approves final design exception. Regional Production Engineer (underneath Director of Preconstruction) recommends design exceptions and serves as the Engineer-of-Record for the project.
- Engineering policy approval.
- Executive Director for Infrastructure -- Final Design
- Final Approval
- Final Approval
- Final approval of design exceptions.
- Final Design Exception Approval
- Final design exception approval, evaluates risks
- Final design exception approval.
- Final design exception approval.
- Final Design Exception approval.
- Final Design, and Design Exception Approval
- N/A
- N/A--Delegated approval of design exceptions to Director of Office of Design
- No, done by committee.
- Non FHWA Facility design exception approval and politically sensitive trade-offs approval.
- none
- None
- None
- Only for exceptions for design speed on our Strategic Intermodal System.
- Policy Approval
- Policy maker/Owner of the design standards
- Recommends Design exception approval.
- Referral and final decision of unresolved design issues (rare).
- Review and Approval
- State Design Engineer -- Establish and approve policy and standards for WSDOT
- Statewide Preconstruction Engineer -- Final Design Exception Approval
- The Chief Engineer is only involved if an issue cannot be resolved at a lower level. This most commonly occurs when other agencies or local or tribal governments are involved.
- The Maryland State Highway Administration currently has two Chief Engineers. The Deputy Administrator/Chief Engineer for Operations (DACEO) oversees Maintenance, Materials, Traffic and Safety, and Construction. The Deputy Administrator/Chief Engineer for Planning, Engineering, Real Estate and Environment (DACEPE) has oversight of the planning and design offices as mentioned in the title. The DACEPE has the final approval for Design Exceptions, however, for projects that are not subject to full federal oversight by FHWA, the Director of the Office of Highway Development can be the approver.

Counsel

- Agreement and contract review/approval
- Assistant State Design Engineer -- Approval of design exceptions.
- Coordinate and assess potential legal exposure
- Counsel is only involved in the design trade-off process if requested by project development staff.
- Design Director--Design evaluation, design exception approval, evaluate risk.
- Division Engineer or State Roadway Design Engineer (submittal to Chief Egr for approval)
- Documentation and Legal opinion on major or high risk trade-offs
- Evaluates risk
- Evaluates tort issues
- Generally none on specific projects. Counsel does perform reviews on new/revised polity
- Legal. Typically not involved in design.
- Legal. Typically not involved in design.

- Legal. Typically not involved in design.
- N/A
- N/A
- N/A
- N/A
- no direct role in the design process
- No, unless specifically requested.
- non involved in design
- none
- None
- None
- None
- None
- None
- None unless asked their legal opinion
- None.
- None.
- Not involved.
- Not typically involved in design exceptions
- occasionally consulted for risk assessment
- Policy issues are developed through coordination with counsel.
- Provides legal advice and assistance to the divisions and districts within the agency, investigating the legality of agency actions and validity of public complaints, drafting proposed legislation and administrative rules, researching and interpreting the law, preparing legal opinions, attending and testifying at legislative committee hearings and performing related duties.
- Provides legal advice for issues that they are approached with.
- Review of the document
- Reviews and Makes Recommendations for approval
- Statewide Traffic Engineer -- Checks exception documentation and evaluates risk determination.
- The closest position for this role would be the Design Chief's for the Highway Design and Community Design Divisions in the Office of Highway Development. However, in some cases this position may reside at the Senior Manager Level in the Office requesting the Design Exception. In the cases of a Design Exception that are requested through a local District Office, the Office of Highway Development is usually included in the review of the Design Exception.
- Typically not involved in design
- Typically not.

Design PM

- Analysis, documentation, recommendation of any design exception to district engineer and/or state design engineer
- Assembles and submits justification and support for design exception request
- Design Chief--Highway Design Office Design evaluation, evaluates risk and design exception documentation.
- Design PM -- Documentation, analysis, recommendations
- Determines risk analysis
- Develops design exceptions and memo to file documentation, documenting design decisions, signs design exceptions.
- Documentation
- Documentation
- Documentation
- Documentation and coordination.
- Documentation, values risk.
- Documentation, values risk.
- Documentation.
- Documents and assesses risk.
- Evaluate alternative provided by the designer -- concur with the selection and get 'Buy in' from upper management/decision makers.
- Evaluates and documents tradeoffs
- Final design exception recommendation.
- Initiates exception process
- Involved in identifying the need for trade-off, analysis, documentation and design exception recommendation for approval by FHWA or Chief Engineer.

- Is involved in the design exception approval
- Makes sure that plans and documents are complete, Project scope will be met and that specifications are followed, attends field checks, makes sure that the project activities are on schedule for each milestone, updates the project schedule with respect to its progress and the rate of plan development if necessary.
- Manage design of projects
- oversees project development and production, documentation and leads public involvement process
- PM--Sign off on designer's form
- Prepares the Design Exception for the Design Chief's approval. We actually have Principal Engineers that put together the final document with the input from our Project Coordinators (In House Design Project Managers)
- Program Manager serves as point of contact for public/political input. Coordinates with shareholders to receive project input. Coordinates multi-disciplinary scoping team meetings and facilitates the design selection.
- Project Engineer -- Manage the design project.
- Project Managers (PM) generally coordinates necessary staff and insure proper documentation for design decisions.
- Proposes solution, documentation
- Provides consultant guidance, coordinates internal reviews
- Responsible for design and application of design criteria and standards.
- Responsible for project development process
- Responsible for project development.
- Responsible for project development. May perform special engineering studies. Documentation.
- Responsible for project/design development
- Review and Recommendation
- Reviews and presents to the Design Exception Committee
- Reviews exception, evaluates risk.
- Technical leader for the PDT
- The Design Project Manager (PM) is responsible for requesting and compiling the documentation supporting any Design Exception. They are also responsible to draft the Design Exception for approval by the Director of the Office of Highway Development or the DACEPE.
- The PM normally reviews design documentation, participates in the discussions concerning trade-off evaluations. They assemble multidisciplinary teams as needed to perform evaluations.
- Yes, provide documentation for exceptions.

Engineering and Planning Specialists

- Assistance with analysis and documentation
- Consulted during the analysis and provides input to the Design PM.
- Design Engineer develops alternatives and cost comparisons, review potential impacts and safety data.
- Design Team -- Manage the design project
- Designers and Design Technicians -- Develop and evaluate trade-offs during design.
- Designs plans and prepares special provision, attends field checks, checks design elements of in-house projects, prepares engineering studies and recommends alternatives for design, coordinates projects with other divisions, agencies and public, computes quantities and prepares draft cost estimate for the project at different stages with respect to the project status.
- Develop and evaluate trade-offs and risk during preliminary design and environmental review stages.
- Develop and evaluate trade-offs and risk during preliminary design and environmental review stages.
- Develop and evaluate trade-offs and risk during preliminary design and environmental review stages.
- Develop and evaluate trade-offs and risk during preliminary design and environmental review stages.
- Develop and evaluate trade-offs and risk during preliminary design, environmental review, and final design (engineers) stages
- Develops and evaluates trade-offs
- Develops and evaluates tradeoffs.
- Develops design trade-offs
- Engineer design--Project Manager, develops highway design plans for construction and evaluates trade-offs and risks during preliminary design.
- Engineering design staff evaluates and finalizes designs by incorporating input from the multi-disciplinary scoping team and other shareholders. They work with Program Management to ensure that the purpose and need for the project has been satisfied.
- Engineers typically design the projects
- Establish purpose and need and design parameters. Develops/reviews design exceptions
- Evaluate Risk
- Evaluate Trade-Offs
- Evaluate trade-offs during design and environmental review stages.

- Identification and initial assessment of trade-offs
- Interactive support of design activities.
- none
- Not involved with design
- Not involved with design.
- On call for evaluation for such areas as traffic engineering or traffic modeling
- PDT members/develop and evaluate trade-offs
- Project Managers (PM) in the Project Management Division (formerly the Project Planning Division) are responsible for compiling a list of trade-offs. Although they are the PM for the project throughout the Planning stage, they have Environmental Project Managers that are assigned to the project throughout the life of the project (panning, design, and construction) to ensure that environmental trade-offs are documented and that the NEPA process is properly followed.
- Proposes solution, documentation
- Provide alternatives/supporting documentation/engineering data/evaluating alternatives.
- Provides data and recommendations for specific components of the project, including life cycle cost analysis.
- Review and Evaluate
- Review and Recommendation
- Specialists are used as requested.
- Subject Matter Experts -- Design support and recommendations.
- Study the trade-offs and makes recommendations
- These are our Designer and they provide all the information for the tradeoffs and risks. It's more of a team process.
- Uses best engineering practices
- Yes, under oversight of PM.
- Yes.
- Yes. Develops and evaluates

Public Information Officer

- As required on project by project basis. Typically not involved in project development or design.
- As required on project by project basis. Where public involvement is more extensive, this person (based at the District) coordinates all public involvement.
- As required on projects by project basis. Typically not involved in project development.
- Communicates trade-offs
- Coordinates communication with public and press
- Coordinates in the Public Involvement process.
- Defines public involvement as two-way communication aimed at providing information to the public and incorporating the views, concerns, and issues of the public in the transportation decision-making process. In addition, the office of public hearing is responsible for ensuring all applicable federal and state laws/regulations are adhered to regarding public involvement and participation activities for federal and state funded projects.
- During the NEPA process and the public meetings, our NDOT Public Information Officer sets up all our meetings, but they are really not involved in the Design Exception process beyond that. The Squads and our Multi Media group produce any displays that Design Squad is unable to create.
- Evaluates community values
- Evaluates what was shown or provided to the public vs. what is going to be built.
- Helps PM gather stakeholder input
- Identifies community requirements for trade-offs, organizes communication of risk and trade-offs.
- Identifies community requirements for trade-offs, organizes communication of risk and trade-offs.
- Informs, communicates and articulates the need for a major or politically sensitive trade-off to the public as needed.
- Link to external stakeholder and community groups
- N/A
- N/A
- N/A
- N/A
- N/A
- No involvement.
- none
- none
- None
- None

- None
- None
- None.
- Not involved
- Not involved in design or project development.
- organizes some communication of risk and tradeoff for controversial projects
- Performed by PM
- PIO -- Assists the Project Engineer with communication outreach efforts.
- Present information to the public/answer questions that the public may come up with.
- Public Information Officer -- Shares information and project status, seeks support
- Role is limited to facilitating the public involvement process. The PM typically participates in the public involvement process.
- The Office of Planning and Preliminary Engineering does have a Public Outreach group that is responsible for coordinating public meetings, developing newsletters, developing displays for the public, and providing mass mailing services for public notices and newsletters. This group provides services to PMs for projects that are in both the Planning and Design phase.
- Typically not involved in design
- Typically, this role is handled by the Program Manager for the project. The functions would be those expressed in the Program Manager description above.
- Yes.

8. When developing project Purpose and Need goals, does your agency typically consider the listed trade-offs as project goals? For each listed trade-off, please select if the trade-off is always, sometimes, or never utilized as a Purpose and Need goal. Also, please select if the measurement of that goal is typically quantitative, qualitative or both.

	As a P&N Goal			Measurement		
	Always	Sometimes	Never	Quantitative	Qualitative	Both
Access Management	6	31	4	8	11	20
Cost	21	18	2	25	2	13
Environmental Issue	21	17	3	2	10	27
Historic Impact	16	22	3	4	14	22
Human Factors/Driver Expectancy	14	21	6	2	19	16
Operational Efficiency	20	21	0	13	5	23
Right-of-Way Availability	16	21	4	14	3	21
Safety	32	7	2	1	5	35
Schedule	12	24	5	20	4	12
Social Concerns	13	26	1	1	25	14
Tort Liability Exposure	9	19	12	2	10	19

9. What type of trade-off is most typically used as a justification for a design decision? Please rank the top 3 by indicating which trade-off is used most often as 1, second as 2, and third as 3.

Trade-Off Most Often Used

Access Management	0
Cost	7
Environmental Issue	4
Historic Impact	1
Human Factor/Driver Expectancy	1
Operational Efficiency	1
Right-of-Way Availability	2
Safety	22
Schedule	2
Social Concerns	2
Tort Liability Exposure	0

Trade-Off Second Most Often Used

Access Management	1
Cost	13
Environmental Issue	9
Historic Impact	3
Human Factor/Driver Expectancy	2
Operational Efficiency	4
Right-of-Way Availability	1
Safety	5
Schedule	2
Social Concerns	0
Tort Liability Exposure	2

Trade-Off Third Most Often Used

Access Management	1
Cost	9
Environmental Issue	11
Historic Impact	1
Human Factor/Driver Expectancy	1
Operational Efficiency	7
Right-of-Way Availability	7
Safety	1
Schedule	2
Social Concerns	0
Tort Liability Exposure	2

All Responses

Access Management	2
Cost	29
Environmental Issue	24
Historic Impact	5
Human Factor/Driver Expectancy	4
Operational Efficiency	12
Right-of-Way Availability	10
Safety	28
Schedule	6
Social Concerns	2
Tort Liability Exposure	4

10. Please indicate on a scale of 1 to 10 how likely your agency is to consider a listed trade-off as a reason for accepting a design decision, with 10 being very likely and 1 being not likely?

Access Management – Average 5.8

1	Not Likely 1
3	2
3	3
3	4
7	5
4	6
11	7
6	8
2	9
1	10 Very Likely

Cost – Average 7.8

0	Not Likely 1
1	2
3	3
0	4
2	5
1	6
5	7
13	8
7	9
9	10 Very Likely

Environmental Issue – Average 8.1

0	Not Likely 1
1	2
1	3
1	4
0	5
3	6
5	7
12	8
12	9
6	10 Very Likely

Historic Impact – Average 7.7

1	Not Likely 1
0	2
2	3
0	4
1	5
2	6
6	7
14	8
8	9
6	10 Very Likely

Human Factors/Driver Expectancy – Average 6.5

0	Not Likely 1
1	2
2	3
5	4
8	5
2	6
9	7
6	8
6	9
2	10 Very Likely

Operational Efficiency – Average 7.3

1	Not Likely 1
0	2
3	3
1	4
2	5
3	6
10	7
9	8
8	9
4	10 Very Likely

Right-of-Way Availability – Average 6.8

0	Not Likely 1
0	2
4	3
2	4
6	5
6	6
6	7
6	8
7	9
4	10 Very Likely

Safety – Average 8.1

3	Not Likely 1
1	2
0	3
1	4
1	5
1	6
5	7
2	8
7	9
19	10 Very Likely

Schedule – Average 5.7

0	Not Likely 1
7	2
4	3
6	4
1	5
7	6
3	7
4	8
3	9
6	10 Very Likely

Social Concerns – Average 5.9

0	Not Likely 1
0	2
7	3
8	4
4	5
3	6
10	7
3	8
2	9
4	10 Very Likely

Tort Liability Concerns – Average 5.3

5	Not Likely 1
3	2
3	3
5	4
8	5
2	6
3	7
5	8
4	9
3	10 Very Likely

11. What methodology, if any, is typically utilized to measure each of the listed trade-offs? For example, methodologies might include expert opinion, state regulation, IHSDM, benefit/cost analysis, etc.

Access Management

- Any additional costs it might add. Operational effects of the roadway, safety
- Benefit cost, context sensitivity.
- Benefit/Cost analysis while taking into account user and community needs as identified in the attached Context Sensitive Solutions (CSS) Vision for CDOT.pdf. Environmental, property and business impacts are all considered.
- Benefit/Cost Ratio
- Business unit's decisions
- Engineering judgment
- Engineering judgment

- Evaluating the existing access regulations against existing conditions and usage.
- Evaluation of operational efficiency, review of type and number of crashes.
- expert opinion
- Expert opinion
- Expert opinion
- Expert Opinion
- expert opinion -- operational improvement, benefit/cost
- Expert opinion, B/C Analysis, Traffic Analysis, State Regulation.
- expert opinion, SCDOT and Federal policies/procedures/guidelines, shareholder input
- Expert opinion, State and Federal policy, laws
- Expert opinion, state regulation
- Expert opinion.
- None
- Opinion as to cost, effect on businesses/residences
- Our Principal and Project Coordinators Expertise, FHWA *Interstate Access Information Guide* and NDOTs *Access Management System and Standards* July 1999
- Policies, directives, and guidelines issued by state and local agencies having permit authority on development and roadway infrastructure improvements as follow:
  - Regulations, codes, and guidelines that are enforceable.
  - Acquisition of access rights by states and local jurisdictions that serve to protect transportation interests and enable sufficient infrastructure is built.
  - Land development regulations by state and local jurisdictions that address property access and related issues.
  - Development review and impact assessments by state and local jurisdictions.
  - Good geometric design of transportation facilities
  - Understanding of access implications by businesses and property owners.
- Policy
- Safety & Level of Service
- Stakeholder input.
- State Highway Access Management Manual
- State law, legal precedent, traditional practice, written access management guidelines
- state regulation
- State regulation
- State regulation
- State regulation
- State regulation
- State regulation
- State regulations
- Traffic and Safety expert opinion
- Traffic delay before and after
- Value Engineer, Environmental Process, Accident History, Design Approval Process, or Design Exception

Cost

- B/C, IHSDM
- Benefit cost analysis
- Benefit cost analysis
- Benefit cost.
- benefit/cost analysis
- Benefit/cost analysis
- Benefit/cost analysis
- Benefit/cost analysis
- Benefit/cost analysis
- Benefit/Cost analysis
- Benefit/cost calc, cost cap (scope, budget)
- Benefit/Cost Ratio
- Budget Management
- Business unit’s decisions
- Calculated values

- Comparison with cost of meeting standards, construction costs compared to environmental mitigation costs, right-of-way and utility costs.
- Cost analysis
- Cost Analysis, general based on expertise and detailed analysis where needed, based on the judgment of the engineers.
- Cost based on bid history of similar projects
- Cost comparison
- Cost comparison, B/C Anal.
- Cost comparison.
- Cost comparison.
- Cost estimate
- Cost/Benefit
- direct measure
- Engineering judgment
- Estimate of the alternatives
- Expert Opinion
- expert opinion, SCDOT and Federal policies/procedures/guidelines, shareholder input
- Expert opinion, state regulation
- Historic unit prices, B/C
- Internal budget analysis
- Opinion
- One of the principal reasons INDOT as a governmental agency invests in better highways is to improve safety. Safer roads reduce the likelihood of personal injuries, property damage and even loss of life to accidents. To determine whether safety and other benefits would be great enough to at least equal the costs of highway investment, INDOT often conducts benefit-cost analyses.

The amounts by which these investments reduce transportation costs are the transportation cost saving or the "benefits". Benefits result from reduction in:

- travel time,
- vehicle operating costs(fuel and wear and tear),
- air pollution and other environmental costs and
- accident risk.

INDOT values these benefits in order to determine whether a project's benefits its costs.

Due to the economic downturn, ongoing structural deficit in the nation, and uncertainty regarding the federal transportation funding, it has already become necessary for INDOT to adopt priority-setting criteria and priorities for the remaining funding now available to implement projects in the near term of the long range transportation plan.

- Risk Analysis (CEVP and CRA), B/C, VE
- Standard estimate form
- Value Engineer, Environmental Process, Accident History, Design Approval Process, or Design Exception
- Value Engineering Study -- State Code
- Whether or not it will add a significant cost to the overall project cost.

Environmental Issue

- 1. National Environmental Policy Act (NEPA) Process. 2. State Regulation (health department) 3. Environmental Stewardship Guide and project Engineer opinion
- Applicable laws and regulations, mitigation opportunities
- Based on Federal Regulations
- Business unit's decisions
- Consideration of value of the resources based on expert opinion and available data, state and federal regulations (obtaining required permits), costs of avoidance and mitigation.
- Consultation with permitting agencies
- Cost of mitigation. Whether the issue could stop the project.
- Engineering judgment
- Environmental Document review
- Environmental evaluation
- Environmental studies/documentation
- Environmental survey

- Evaluation of impacts
- Expert opinion
- Expert Opinion
- expert opinion, SCDOT and Federal policies/procedures/guidelines, shareholder input
- Expert opinion, state regulation
- Federal & State Regulations
- Federal Regulation
- Federal regulations, Expert Opinion
- Federal regulations.
- Federal/state regulations
- In most cases we don't have a formal system for making those evaluations. The only one that is formal would be our design standards for low-volume roads. That allows different design standards for bridges where there's less traffic, and it makes it more likely we will be able to preserve historic bridges that wouldn't meet current design standards. For other types of impacts we have to make a reasonable effort to avoid resources like wetlands, historic properties, etc. as long as it won't force us into designing a road that won't function well. Those decisions are made in NEPA and in permitting.

  Almost all trade-offs are coming from State or Federal regulation or State or Federal Regulatory Agency opinion on a project by project basis. Any guidance OES provides to designers is usually based on our expert opinion or perception of what the regulatory agency or regulations are going to require in order to acquire our permit. At the end of the day, the law and those that enforce it determine whether we have a project that is permit-able, and if not, further trade-offs or costs are typically needed.

  For cultural resources, working within federal register, tradeoffs most typically occur as mitigation items. For example, if a design includes destruction of a significant archaeological site we will first attempt to avoid it through redesign. The eligibility of the property/site for the National Register of Historic Places determines whether a site is significant enough that mitigation should occur. If avoidance is not possible, we would recover as much data from the site as is reasonable. In rare cases we cannot mitigate out and cancel the project.

  Any mitigation would be passed by consulting parties consisting of state and federal regulators, preservationists, members of the public.
- Law/Regulation
- Mitigation
- NEPA requirements and public opinion.
- Resource Agency coordination, context sensitivity
- state & federal regulations, ability to mitigate, ability to get the action permitted
- State and Federal policy, laws
- State and federal regulation with community input
- State and Federal regulations
- State or Federal regulation, cost analysis.
- state regulation
- State regulation
- State regulation
- State regulations, benefit/cost analysis, expert opinions.
- State regulations, historic mitigation costs, We MUST satisfy permit requirements.
- State/Fed Regulations
- Value Engineer, Environmental Process, Accident History, Design Approval Process, or Design Exception

Historic Impact

- 1. National Environmental Policy Act (NEPA) Process 2. Expert Opinion
- Applicable laws and regulations, mitigation opportunities
- Based on Federal Regulations
- Business unit's decisions
- Community value
- Consideration of value of the resources based on expert opinion and available data, state and federal regulations (obtaining required permits), costs of avoidance and mitigation.
- Consultation with SHPO
- During the era of Interstate construction from the 1950's to the 1980's, a number of instances of new highway construction had a devastating impact on communities and areas of environmental sensitivity. It is readily acknowledged that there will be some degree of physical impact on the surroundings associated with the construction of any new location highway or major recon-

struction or widening of an existing highway facility. However, from the perspective of horizontal and vertical alignment, much of this impact can and should be alleviated.

Impact on the surrounding environment can be minimized by careful attention to detail during the route location and preliminary design phases and a willingness of all concerned parties to work together toward a common goal. In an effort to highlight Flexibility in Highway Design and in order for minimizing and or, totally avoiding historic impact to the U.S. Land marks and the environment, INDOT applies a series of Context Sensitive Solutions which includes an Overview of the Highway Planning and Development Process such as the following design guidelines: *Highway Design Standards, Functional Classification, Design Controls, Horizontal and Vertical Alignment, Cross-Section Elements, Bridges and Other Major Structures, Intersections* as well as the use of nonstandard design when such use best satisfies the concerns of a given situation through an exception process.

- Engineering judgment
- Environmental Document review
- Environmental evaluation, State Historic Preservation Office
- Environmental studies/documentation
- Evaluation of impacts
- Expert opinion
- Expert Opinion
- expert opinion, SCDOT and Federal policies/procedures/guidelines, shareholder input
- Expert opinion, state regulation
- Federal & State Regulations
- Federal & State Regulations; Level of public and political input.
- Federal regs, expert opinion, State regs.
- Federal regs.
- federal regulation
- Federal Regulation
- Federal/state regulations
- If the issue could stop the project.
- Law/Regulation
- NEPA requirements, federal law and public opinion.
- state & federal regulations, ability to mitigate, ability to get the action approved
- State and Federal policy, laws
- State and federal regulation with community input
- State and Federal regulations
- State or Federal regulation, cost analysis.
- State regulation
- State regulation
- State Regulation
- State regulations
- State/Fed Agency coordination.
- Value Engineer, Environmental Process, Accident History, Design Approval Process, or Design Exception

Human Factors/Driver Expectancy

- AASHTO Policy on Geometric Design of Highways and Streets and input from our Traffic Safety Engineers.
- B/C, Expert opinion
- Benefit/Cost analysis when safety is considered explicitly.
- Business unit’s decisions
- Drivers safety
- Engineering design review
- Engineering judgment
- Engineering judgment
- Engineering judgment, research findings, IHSDM
- Evaluation of the design
- expert opinion
- Expert opinion
- Expert opinion
- Expert opinion
- Expert opinion

- Expert opinion
- Expert Opinion
- Expert Opinion
- Expert Opinion
- expert opinion, SCDOT and Federal policies/procedures/guidelines
- Expert opinion, state regulation
- Expert opinion, Traffic anal., B/C anal. IHSDM
- Expert opinion, traffic analysis, highway capacity manual.
- Expert opinion, traffic modeling, State and Federal policy
- Expert opinion.
- Expert opinion.
- Expert opinions
- Functional classification
- Human Factors/Driver Expectancy do not adequately address trade-offs between conflicting demands that are related to important road user characteristics. Amongst some of these factors are: Age, Alcohol, Experience, Familiarity, Memory, Vision, Weather, Distraction (phone- use/texting), Stopping Sight Distance, Decision Sight Distance…etc.

  Drivers also make trade-offs between speed versus control when executing maneuvers. The AASHTO deceleration value of 3.4 m/s^2 represents an estimate of a "comfortable deceleration" with which almost all drivers can maintain good vehicle control.

  To aid highway designers and traffic engineers in making trade-offs, expert judgment and design convention with little or no empirical data are used to develop guidelines. Other guideline based equally on expert judgment and experimental data were also developed in order to aid highway designers and traffic engineers in making trade-offs.

- MUTCD
- MUTCD, AASHTO *Green Book*, other
- None.
- older drivers
- Standard/expert opinion
- The road design is consistent in design along the corridor.
- This is tied to safety evaluations. A review of standards and guidelines, as well as the crash history, is performed to determine if we are adequately addressing drivers' safety. Benefit-cost ratios and expert opinion are used in making the final decisions.
- Traffic and Safety expert opinion
- Value Engineer, Environmental Process, Accident History, Design Approval Process, or Design Exception

Operational Efficiency

- Based on input from our Traffic Information Division and our Operations Traffic Analysis Section.
- Benefit cost, expert opinion.
- Benefit/Cost analysis supported by some form of traffic modeling. This is generally defined by congestion and measured by the Level of Service.
- Business unit's decisions
- Current geometric design guidelines for highways and streets do not adequately accommodate the needs of all potential users. Pedestrians and bicycles are common users of the urban and rural transportation network, especially at intersections. A possible approach for addressing this issue is the tradeoff between design elements for vehicles and other users.

Capacity expansion is still the primary means the region looks to satisfy growing mobility needs, and there is not comparable screening applied to examine trade-offs between a management strategy and a capacity improvement. Research is needed to provide guidance to highway designers on trade-offs of shoulder and lane width selection in freeway, US route and the State route corridors.

Highway designers need guidance on the operational and safety impacts for cross section design trade-offs while trying to balance corridor capacity, project costs, public involvement and environmental impacts. The trade-offs between operational benefits and safety need to be quantified. At INDOT expert highway engineers as well as operational and safety guidelines provide such guidance to all the practitioners throughout the State.

Shoulders are often used as the separation between special use lanes and the general purpose lanes. The impacts of providing or not providing barrier separation need to be determined. Further, when barriers are used, what shoulder widths are necessary adjustments to the barrier and what safety impacts result from these shoulder widths is a concern. It directly reflects the continuous nature of the relationship between service, cost and safety, and changes the value of design dimensions. It reinforces the need to consider the impacts of trade-offs throughout the domain and not just when a "standard" threshold is crossed.

- Engineering judgment
- Engineering operational analysis/capacity analysis
- Evaluation of the design
- expert opinion
- Expert opinion
- Expert opinion
- Expert Opinion
- Expert Opinion
- Expert opinion and calculated LOS
- expert opinion, modeling
- expert opinion, SCDOT and Federal policies/procedures/guidelines
- Expert opinion, state regulation
- HCM
- HCM and expert opinion
- Highway Capacity Manual
- Highway Capacity Manual, other
- Level of Service
- Modeling of the operational characteristics is done to determine capacity needs and congestion issues. Anticipated future growth is also considered.
- None.
- Operational analysis, traffic studies, site inspections
- Simulation modeling, traditional capacity calcs (HCM), UK Empirical method (roundabouts), *Green Book*/MnDOT design criteria for freeway ramp length, engineering judgment
- State Growth Management Regulations, Highway capacity analysis
- State Regs
- Traffic analysis
- Traffic analysis using traffic modeling software
- Traffic analysis, expert opinion
- Traffic analysis, IHSDM
- Traffic analysis.
- Traffic modeling, State and Federal policy and laws
- Traffic studies and capacity analysis.
- Traffic Studies/traffic simulation
- V/C Ratio
- Value Engineer, Environmental Process, Accident History, Design Approval Process, or Design Exception
- Whether the design meets efficiency goal

Right-of-Way Availability

- ability to obtain necessary ROW w/in job timeframe, cost, economic or community impact
- Applicable laws and precedents, department policy & practice
- Appraisals
- B/C, State and Federal policy and laws
- Benefit cost.
- Benefit/Cost
- Benefit/Cost analysis while taking into account the ‘Purpose and Need’ statement for the project.
- Benefit/Cost Ratio
- Budget Management
- Business unit’s decisions
- Cost and acquisition impacts
- Cost comparison and need for condemnation.
- Cost comparison, B/C anal.
- Cost comparison.
- Cost/benefit analysis.
- Cross-sections
- Engineering judgment
- Engineering judgment and cost
- Estimate of ROW impacts

- expert opinion
- Expert opinion
- expert opinion, SCDOT and Federal policies/procedures/guidelines, shareholder input
- Expert opinion, state regulation
- INDOT project Manager or project engineer will make enquiry and communicate with the right-of-way cost estimator in order to provide input on probable design scenarios that will impact the right-of-way requirements and cost, and the potential trade-offs between right-of-way and design may be discussed. The estimator's experience and knowledge of the area are very important in establishing a preliminary right-of-way cost.

  Options that directly affect the right-of-way function occur when implementing the real property acquisition and management required by the current and future transportation network. Agencies have choices in the following areas:

  – the " human factor" can be defined as the uncertainty and unpredictability related to dealing with property owners when an agency is attempting to acquire their property;
  – trade-offs between utility relocation expense and acquisition of additional right-of-way;
  – access management provisions (capacity versus operation);
  – property management practices (maintenance).
- Measured/observed values
- Only applies to low cost safety projects or capital projects.
- Preliminary design reports
- Quantitative
- Relocation costs
- ROW docs and estimates
- Site inspection, appraisal reports, benefit/cost analysis
- State regulation
- State Regulations, Maps, historic costs
- The Chief ROW Agents expertise on ROW availability/cost and project schedules.
- This is strictly a cost-based evaluation. Will acquiring the necessary right-of-way cost more than the construction cost necessary to avoid acquisition.
- Using Tax Maps minimal/Metes & Bounds survey and Plats for more detailed impacts
- Value Engineer, Environmental Process, Accident History, Design Approval Process, or Design Exception
- VDOT policy/federal & state regulations

Safety

- Accident analysis.
- Accident data and analysis, Safety Management Systems
- Accident Data combined with the new *Highway Safety Manual*. We have just started to become familiar with the *Highway Safety Manual* and it's use for predicting accidents to justify accident reductions.
- Benefit/cost
- Benefit/Cost
- Business unit's decisions
- Collision analysis, Highway safety issues group, State and Federal policy and laws
- Crash analysis
- crash analysis, expert opinion, design criteria
- Crash histories and construction costs are evaluated to determine cost effective treatments. All other impacts associated with the proposed design must also be evaluated. The design features are compared with state and national guidelines to determine the final design (expert opinion).
- Crash history, applicable research, engineering judgment, *Highway Safety Manual*, IHSDM, *Green Book*/MnDOT design criteria
- Crash history/expert opinion
- Engineering judgment
- Engineering judgment
- Evaluation of the design
- expert opinion
- Expert opinion
- Expert Opinion
- Expert opinion, design criteria
- Expert opinion, design criteria

- Expert opinion, design criteria, Traffic anal. State and Fed. Regs.
- expert opinion, safety data, benefit/cost
- expert opinion, SCDOT and Federal policies/procedures/guidelines, shareholder input
- Expert opinion, state regulation
- Expert opinions
- History at location being considered for improvement. Analyze existing geometry and look for deficiencies as they relate to AASHTO
- IHSDM
- Never compromised.
- Qualitative and Quantitative
- Roadway designers intent to provide a safe facility addressing mobility concerns, accommodating the physical and social environment and within financial constraints. Sometimes, tradeoffs among these may be needed to deliver the desired project and designers need tools to estimate the safety implications from such decisions.

  INDOT designers make sure that all the minimum safety regulations and requirements set forth by the Federal Government Agencies, local agencies, as well as, its own minimum safety requirements are applied and that there will be no compromise rendered with any safety related issue.

In an effort to highlight Flexibility in Highway Design and in order to reduce the total number of crashes, INDOT applies a series of Context Sensitive Solutions which includes an Overview of the Highway Planning and Development Process.

An understanding of the safety consequences for both the total number and level of severity is of interest in evaluating trade-offs of design elements. The changes in the total number of crashes will provide an understanding of the overall safety risks of the trade-offs applied. It is possible that trade-offs for a design element may not show significant impacts on roadway safety expressed in total crashes but there may be an effort on the severity of the crashes.

- RSAP, (*Highway Safety Manual* in future too), historic crash data, benefit/cost analysis.
- Safety analysis
- Standard/expert opinion
- State regulations, crash data and analysis
- Tort issues
- Traffic and Safety expert opinion
- Unlikely design would be compromised to improve safety
- Value Engineer, Environmental Process, Accident History, Design Approval Process, or Design Exception
- We address safety explicitly using SPFs (Colorado specific Safety Performance Functions) and Diagnostic Tools (Pattern Recognition Analysis) in concert with risk analysis and Benefit/Cost analysis

Schedule

- Actual dates
- Benefit cost.
- Benefit/Cost analysis and expert opinion.
- Business unit's decisions
- Construction Expert
- Construction Program
- CPM schedules (rough draft) based on history
- Engineering judgment
- expert opinion
- Expert opinion
- Expert opinion
- expert opinion, approval by the appropriate SCDOT and FHWA staff, shareholder input
- Expert opinion, Cost, Environ. Concerns (e.g. nesting, migration patterns, etc..)
- Expert opinion, state regulation
- Historic/Similar projects.
- Impact on the Program and additional cost caused by delaying a letting
- Letting schedule
- Loss of funding
- N/A
- Needs to meet the schedule to get the funds set aside for the project.
- None
- None.

- On occasion projects have critical Advertising dates to meet funding years. ROW/Utilities can be difficult to acquire in a short time frame, so design exceptions are chosen to ensure that projects meet advertising deadlines. Environmental may also affect the schedules.
- Primavera
- Primavera
- Quantitative
- Risk Analysis (CEVP and CRA), PM tools
- Scheduling software i.e. Primavera
- State regulations, traffic management plan
- The two key questions being asked by the decision-makers are:
  - "how can we do it cheaper?"
  - "how can we do it faster?"

One way to answer these two questions the executives always ask goes like this:

"Yes we can do it faster and cheaper", followed by a summary of the principal trade-offs for the executive-consideration.

To be able to present choices like those above, we need to develop project schedules the way the pros do. First, we need to think of our projects as cream-filled Twinkies. When we squeeze one corner of the Twinkie the filling oozes out the others. That's an elegant example of a project trade-off. Projects are delicate. Just about everybody understands that when we take away resources, the duration is going to increase. When we want to increase the certainty of finishing a project by a specific date, the cost will increase as we "buy" risk insurance. These are the trade-offs that decision-makers should be able to assess. Some more common trade-offs that always challenge a project's schedule are; modifications to a project's Scope, budget and or risk.

In an effort to highlight Flexibility in Highway Design and in order to measure and or, counter measure the values and the consequences for the above trade-offs the, INDOT applies a series of Context Sensitive Solutions which includes an Overview of the Highway Planning and Development Process.

- Typical planning, project management and flowcharting methods
- urgency of the action
- urgency, future projects
- User costs analyses are performed to determine if accelerating construction schedules are needed. These typically don't result in design deviations/compromises. Rather, specific construction methods may be required to reduce construction time and associated user cost.
- Value Engineer, Environmental Process, Accident History, Design Approval Process, or Design Exception
- VDOT policy

Social Concerns

- Applicable laws & precedents, judgment
- Business unit's decisions
- Community acceptance
- CSS
- During NEPA public information meetings input from the public for any number of reasons, may affect the geometric design of a project. Nevada requires a resolution of support from the local entity that the project falls within to proceed with the project for any new construction roadways.
- Engineering judgment
- Engineering judgment
- Environmental evaluation
- Evaluation of Impacts and comments at public meetings
- expert opinion
- Expert opinion
- Expert opinion
- Expert Opinion
- expert opinion, approval by the appropriate SCDOT and FHWA staff, shareholder input
- Expert opinion, state regulation
- Highway safety continues to be a major social issue. More than 39,000 motor vehicle fatalities occurred in the United States in 1992 and more than 300,000 severe injuries were caused by motor vehicle accidents. Safety is a key issue in the selection and development of highway-widening projects. Mitigation of safety problems begins by examining accident records to identify dangerous section of highway and causative factors.

The Indiana State Department of Transportation (INDOT) defines the Context Sensitive Design approach to project development as the way it does business for all highway projects. This is based on the understanding that an effective transportation system provides safe, efficient, dependable and environmentally responsible transportation services to all of its users.

Context Sensitive Design (CSD), Context Sensitive Solution (CSS), Flexibility in Highway Design…Whatever name is chosen to define these principles, the philosophy remains the same. CSD provides a project that meets the purpose and needs as defined by the highway users, local community and the State. It ensures projects are developed to maintain the safety and efficiency of the facility for its users and the community. INDOT projects add to the livability of the community because they preserve environmental, scenic, historic, aesthetic and natural resources values of the area, as memorialized in the INDOT Context Sensitive Solution.

- Impact Matrix
- Impact Matrix, Public input
- Impact Matrix.
- NEPA process.
- Opinion
- property acquisition, tax base and development impacts
- public controversy, perceived potential for economic development, cost
- Public Information Officer
- Public input
- Public involvement through the environmental/preliminary design process
- Public Opinion/Federal Regulation
- Public outreach
- Public outreach process used to ensure public input. Use newsletters, websites, storefronts, public meetings...
- Refer to the attached Context Sensitive Solutions (CSS) Vision for CDOT.pdf. Expectations from Stakeholders and community goals may be used to determine trade-offs.
- Site inspections and interviews
- Social concerns are addressed through the public involvement process. The biggest issues tend to be in urban/suburban areas (such as they are in Montana). We try to distinguish between loud noise and real societal concerns. The proposed design compromise is assessed against potential safety effects and costs.
- Stakeholder comments
- Stakeholder input
- Stakeholder input.
- State and federal regulation with community input
- Value Engineer, Environmental Process, Accident History, Design Approval Process, or Design Exception

Tort Liability Exposure

- AG opinion or Legal Counsel opinion when needed
- Business unit's decisions
- Design standards
- During the NEPA process there are occasions when letters are received from attorneys representing both public and private interests have threatened tort claims during the preliminary design phases that have influenced the design of projects.
- Engineering judgment
- Enterprise Risk Management Matrix
- expert opinion
- expert opinion
- Expert opinion
- Expert opinion
- Expert opinion
- Expert opinion
- Expert opinion
- Expert Opinion
- Expert Opinion
- expert opinion, SCDOT and Federal policies/procedures/guidelines
- Expert opinion, state regulation
- Expert opinion.
- Expert opinion.
- Expert opinions and legal advice
- Legal counsel

- Legal counsel
- Legal counsel, State and Fed. Regs., Expert opinion
- Legal counsel.
- N/A
- Never compromised, Regional Safety Review committees review all projects.
- None
- Not a big concern. We believe if we have done an accurate evaluation, the design features will be defensible. The tort claims are both diverse in nature and locations, so attempting to incorporate tort-specific design features would be ineffective.
- State law governing immunity
- State/Fed regulation
- The system of streets and highways in the United States covers many thousands of miles of road surface constructed of various kinds of materials and designed for a variety of vehicle types and operations. The extensive use of the streets and highways inevitably results in a large number of motor vehicle accidents that annually cause thousands of deaths and personal injuries and extensive amounts of property damage. In the legal actions that follow, it is not surprising that the design and construction of the roadways on which such accidents take place should be brought into a case as possible bases for a finding of liability.

  Legal actions dealing with highway design and construction may involve issues related to deficiencies in the configuration, structure, and materials of a highway itself, appurtenant structures such as guardrails and light poles, or the types of signs and other warning devices employed along a roadway. Governmental units involved in such actions may argue that their conduct in the planning and design aspects of a highway construction project involves uniquely governmental functions calling for the exercise of discretion and the making of policy decisions, and they may thus assert that they should be immune from suit in such cases. Tort liability of governmental entities is often dealt with by statutes referred to as tort claims acts, which may specify the types of governmental actions that may be made the subject of lawsuits. Contractors involved in such a legal action may argue in their defense that they should be relieved of liability because their operations were conducted in accordance with the requirements and specifications of a government contract and that their operations were properly carried out under those requirements and specifications.

  Tort law, the branch of the law that deals with the recovery of damages for private injuries or wrongs not arising out of contractual relationships, has developed in the United States under the separate legal systems of the individual states, supplemented by a body of decisional law established in federal courts throughout the country, rather than out of a single unified body of federal law. As a result, the legal standards governing cases in which issues related to highway design and construction are raised will vary from state to state.

  The Indiana State Department of Transportation (INDOT) defines the Context Sensitive Design approach to project development as the way it does business for all highway projects. This is based on the understanding that an effective transportation system provides safe, efficient, dependable and environmentally responsible transportation services to all of its users. These principles are applied to all of INDOT projects. Whence, Indiana Department of Transportation does not accommodate trade-offs when and where matters of public safety is a concern.
- Traffic and Safety expert opinion
- Value Engineer, Environmental Process, Accident History, Design Approval Process, or Design Exception
- VDOT policy

12. How does your agency document design decisions (beyond design exceptions)?

- 1. Safety Assessment reports 2. NEPA documentations. 3. Design Decision letters to the file 4. Meeting minutes (e.g. scoping, FIR and FOR, meeting minutes) 5. PS&E construction packages 6. Stamped PS&E record sets submitted to Central files at Headquarters (archive set)
- Anything that does not meet our design standards is either approved or denied during our Preliminary Design Field Reviews for our projects. Our Road Design Guide, Standard Plans for Road and Bridge Construction, etc usually have notes that request written approval from the Chief Road Design Engineer for any exceptions.
- Correspondence mainly by e-mail
- Correspondence.
- Correspondence/Project file
- Decisions leading up to trade-off in design is documented in project folder.
- Design approval documents (reports) require that certain project elements be reviewed, analyzed and documented, then compared across the range of alternatives. Decisions made post-design approval either require a reevaluation of the design approval (a process we have documented), others require only a note to the project file (along with individuals with responsibility/interest in the decision), depending on the scope and potential impact of the decision.
- Design Communication Report to document any design changes considered significant.
- Design criteria are listed on a standard form for each project.
- Design decisions are documented in preliminary engineering report.

- Design decisions are documented through Scoping Reports as well as the use of project files. Informally the design decisions are documented through emails.
- Design Documentation Package
- Designer Logs; Emails, Review Meeting Minutes
- Environmental documents (FONSI, CE, FEIS, EA), re-evaluations, Environmental Checklists
- Formal design exception committee where DE are recorded and tracked
- Formal Design variance request which is similar to the design exception process. For guidance, documentation in a Design Data Book.
- Formal documentation and approval process outlined on design manuals.
- Functional design report, environmental documents
- In a project file
- In project files
- In the project file in the environmental documentation through the project selection process
- In writing.
- INDOT utilizes various means of systems for documenting and or, record keeping of its projects- activity -logs as well as the final status of a project which has been awarded a contract and the construction is complete. The list below with individual descriptions represents few of the systems which INDOT utilizes for each project activities records:

  Contract Information Book (a legal document containing contract information, construction plans, special provisions, contract No. and a letting date certified by the project engineer).

  INDOT Project Commitment Database (IPCD), is an Intranet-Site help file. Projects contained within these files involve commitments which are to be carried out in respect to a project's particular need and or a requirement.

  Scheduling Project Management Listing (SPMS)/INDOT FULL PROJECT LISTING. Is a project management tool that provides a highly productive environment for managing project data resources, scheduling, estimating, and funding. SPMS reports summarize data from various perspectives, including current project activity schedule baseline versus actual dates project cost versus budget cost.

  Electronic Records Management System (ERMS) is INDOT'S repository of official documents. ERMS store the documents with an indexing database that is analogous to the catalogue in a library.

  The electronic document types being stored in ERMS at this time include, but are not limited to, Word documents, Excel spreadsheets, Adobe PDF, Powerpoint presentations and images (.TIF, JPG, etc.) ERMS can store more than hundred electronic file formats.

  There is an FTP application for external users to upload files into ERMS. Finally there is a web portal INDOT (IWP) – that serves as the main gateway to ERMS and directs users to different areas within ERMS.

  INDOT Management Information Portal (MIP) draws most data from the Data Warehouse (DW), which is updated before the start of business every day. MIP is a web based file and can be accessed through, http://intranet.indot.state.in.us/bits/helpdeskin.htm.
- It varies by district. The PD&E report contains trade-offs made early in the development process. The Preliminary Engineering Report documents decisions before final design phase.
- Letters to project files.
- Meeting minutes of the Project Development Team
- Memos, letters and design decisions in the permanent history files
- Official environmental documentation, Design Memorandum, informal documentation in project design file
- plan reviews and reports
- Project documents
- Project Managers maintain project files with calculations and supporting documentation. These files are subject to the state document retention policy and have a defined retention period. No additional documentation beyond design exception is generally performed.
- Project related memorandums, emails, and other correspondence is maintained by the Program Manager and Design staff as part of the project files.
- Reports, letters or emails
- Review with the Chief Engineer and document in a report
- Scope document, design documentation
- See section 1C-8 of Design Manual, but note that this is relatively new. Previously a less formal process of noting decisions in the file.
- The design decisions are generally documented in milestone reports. Separate reports may be necessary when design compromises occur outside of the timeline of these reports. We have general guidelines as to what information the documentation

should contain. The final plan checking process reviews the design decisions to ensure proper documentation and to ensure that the design elements have been included in the plans.
- The project manager during the design stage is responsible for documentation of his/her own project.
- Through PDT meeting minutes.
- Typically trade-offs in the design process and covered by a memo to the project file describing the circumstances, design standards, associated impacts and reasoning as to why the ultimate decision was made.
- Value Engineer, Environmental Process, Accident History, Design Approval Process, or Design Exception
- Written documentation placed in the project file. Design Exceptions and Design Waivers have their own VDOT forms which are placed in the project file and their own database.

13. In instances where a range of values may be acceptable for design purposes, how does your agency determine what value will be utilized for design purposes?

- Assuming that right-of-way and environmental impacts are acceptable for the entire range of treatments, we compare costs for the minimum treatment with the desirable treatment. We then try to determine if spending additional money will result in a worthwhile benefit. Safety is a key consideration and is assessed through a review of crash history.
- B/C, traffic, environmental, ROW, utility, etc...
- Based on available budget as well as safety.
- Based on safety history, project area context and engineering judgment. Cost is a Factor.
- Case by case basis depending on highway classification, traffic volumes, and adjacent highway segments, location, project type, and project purpose and need.
- Consideration of issues identified in question 11
- Designer determines best design with input from multi-disciplinary project management team
- Designer determines the value with ultimate approval by Roadway Design Engineer
- Designer determines the value.
- Engineering discretion is utilized by the Engineer-of-Record to determine the most appropriate design solution. If practical, we avoid using minimum design criteria.
- Engineering judgment.
- Engineering judgment.
- Engineering Judgment.
- Expert opinion of Design Staff
- Expert opinions considering the values under consideration and the quantitative values available.
- Generally the lowest value is selected.
- Guidance is provided in governing state design criteria; decisions and judgments are made by project designers and/or central office staff depending on degree of delegation
- If possible, the most conservative number is usually used.
- In our Road Design Guide we have major tables that have the 13 critical elements of design and more. We show a desirable standard and a minimum standard and we try to meet the desirable. We capture what we will be using for that particular project in the design report. If we don't meet the minimum, we require a written exception for the project files.
- location by location based on specific circumstances
- Lower cost.
- Minimum value unless otherwise necessary
- Minimum values are used for design purposes (to control cost and impacts) unless there is a reason to use a different value.
- Our PPM states the value to be used. Deviations from these are documented as Variations.
- Project Manager determines the value in combination with geometric staff review
- Project managers decision based on context and whether project is new construction rehabilitation.
- Project Team makes the determination collectively, though the District has the greatest influence.
- Safety remains the same or is improved and public needs are being met on the project. On more complicated projects this could involve a value engineering study where a weighted design matrix is created to document the decision. Sometimes benefit/cost matrix are created through applications, such as IHSDM, RSAP or travel capacity applications to balance public needs with perceived risks. Lesser decisions are done through engineering judgment and documented accordingly.
- Safety would be considered as the most important factor
- Start with highest value and work down (if necessary) based on safety, rights of way and cost.
- State specific design guide outlining allowable as the norm. Desirable only used in rare occasions.
- The Agency initially specifies the minimum design value that meets the requirements for the facility type, budget and the 'Purpose and Need' statement for the project. Then using the guidelines in the attached Context Sensitive Solutions (CSS) Vision for CDOT.pdf all stakeholders are given the opportunity to comment on the selected value throughout the design process. This is a collaborative process between the agency and all stakeholders.

- The Department's intent is that all design criteria described in the State and federal regulations, manuals and guidelines be satisfied. If practical, the proposed design should exceed the minimum or lower criteria. If a range of values is provided, a design which is near the upper value should be provided. This is intended to ensure that the Department will provide a highway system which satisfies the transportation needs of the State and provides a reasonable level of safety, comfort and convenience for the travelling public. However, recognizing that this will not always be practical, the Department has established a process to evaluate and approve exceptions to geometric design criteria.
- The least impact.
- Try to get the higher value, but go with a lower value if controls warrant it.
- Typically, it is left up to the designer and/or project manager's decision. We avoid the lowest value in the range when possible.
- Use Engineering judgment of the Engineer of record within the range of accepted values.
- Using engineering judgment balancing costs and impacts to benefits
- Values within ranges are intended to more closely tailor the design elements of a project to its surroundings. For instance, lane width is given as 10-12 ft. The 10 ft. value is appropriate for low-volume local roads while the 12 is used for principal arterial expressways and freeways. Indecently, this is what MoDOT believes to be true context sensitive design. Generally, the lowest value that will provide the purpose and need in a safe, effective manner, is the chosen value.
- VDOT encourages the use of the safest design values possible for the design of a project. Minimum values provided in the AASHTO *Green Book* are not encouraged; however they represent the minimum value that can be utilized in project design without a design exception.
- We typically specify discrete values, not ranges, for design criteria.
- within the range of acceptable values, expert opinion is used

14. Does public involvement play a role in the approval process for a trade-off in the design selection process?

31 Yes

11 No

If yes, please explain how PI impacts the process.

- 1. Public involvement impacts the decisions made at the Environmental Impact and Environmental Assessment Studies. 2. Preliminary design values are presented or made available to the public which include all stakeholders and facility users for comments. Their goals and comments guide the agency to seek transportation solutions that fit the projects context.
- Community acceptance during the public hearing process
- During the NEPA public information process we answer all inquiries and document our answers. We also meet with neighborhood groups, Citizens advisory committees, etc and address their concerns. Many times if it's very sensitive on our large projects we form working committees that come up with the solutions. These working groups also allow NDOT to present our standards, funding issues, construction problems, etc that are affecting the project. The final decisions fall on NDOT, but the input from the committees helps make the decision.
- Especially on larger projects, stakeholder input is considered for items that will not adversely affect safety.
- Feedback from Public Officials and general public is considered for suggestions, buy-in, and Resolution of Support.
- If the public involvement process indicates that the affected landowners, business people and road users are willing to accept the downside of the trade-off, it is more likely to be approved.
- If there is an acceptable range of values, we defer to PI within the range.
- Local and regional input is mandatory during the design exception process. Otherwise, local input is obtained and used in the evaluation.
- Local knowledge of traffic/pedestrian/bicycle/safety issues. Public input is used in conjunction with measurables/background information gathered for planning.
- Maine has a very extensive public process
- Not usually, but could.
- Note: Public involvement plays a role in the trade-off process but not the final approvement.
- Only for environmental/historical tradeoffs.
- Only if the trade off was requested by the public.
- Public input is one of many factors that go into the design process. Information and sentiment is gathered and weighed along with competing and complementary factors.
- Public involvement is key to alternative selection; however, they are generally not involved in risk analysis comparisons.
- Public involvement plays an important role as public input is solicited during all phases of project development, in particular during the environmental impact assessment and design phases. During design, public and community stakeholder involvement

is paramount because it is at this point we (INDOT) can present a greater level of detail rather than just concepts and illustrate visually the proposal at hand, garnering tangible feedback from the public, in addition to describing impacts.

- public meetings
- Public opinion & expectation of project elements
- Public opinion and human impacts are part of the trade-off analysis.
- Rarely
- Shareholder input is received by the Program Manager and utilized to evaluate the design for a project.
- Some projects have members of the public on the PDT. Other times there are public meetings held to evaluate different proposals.
- Sometimes. If the PI leads to a decision where the trade-off is used.
- Stakeholder input is considered when making design decisions.
- structure & shoulder width shared with non-motorized, signalization, laneage in coordination with commercial/residential development
- The design can have a community impact, so those have to be balanced in some cases
- The public involvement process begins during project scoping and continues throughout the project process. Information obtained as part of the PI process informs the decisions made during scoping and design. If there is controversy regarding a planned design decision, that decision may be reviewed and even reconsidered in light of public opinion/information, and a different design outcome may result.
- Understanding project area context is developed through public involvement.
- Use of public meetings and project design open houses.
- VDOT will hold a Citizens Information Meeting to present an issue(s) to the public for their review. Comments are received by VDOT and included in the assessment of the design issue.
- We seek their input and attempt to get public buy in and acceptance to the maximum extent possible.
- Work with the public to incorporate their comments on options
- Yes from the standpoint that public opinion may cause us to revise certain features. The public doesn't get to "vote" on design compromises.

15. How do you communicate the results of design decisions that have been made based on trade-offs in the design selection process to the general public?

- 1. Press releases. 2. NEPA documentations. 3.Public Meetings and Open Houses 4. Stakeholder meetings (Local governments, utility groups, etc) 5. Project Scoping Meetings 6. Field Inspection Review, FIR, Meetings 7. Final Office Review, FOR, Meetings 8. Community outreach programs such as mailings, emails 9. CDOT Website 10. Local governments and utility groups are invited to all project scoping, FIR and FOR meetings
- All aspects of the project are open to the general public and decisions that directly impact them are publicized. In recent years, community relations staffers have become critical players both in the Central Office and the Districts.
- At community meetings.
- By means of a Citizen Information Meeting and/or updated information on the internet.
- Don't
- During the development of projects, many of the public involvement activities take place during the development of the environmental impact assessment and design phases. Formal NEPA public involvement activities take place at this time which allows those activities (public hearings, public notices soliciting comment, project newsletters, websites, etc) to be fully documented within the environmental document for any given project. At the completion and approval of the environmental document, INDOT's Public Hearings Office will notify the public and community stakeholders via public notice, project correspondence via U.S. mail and/or electronically disseminated, announcements posted onto INDOT's webpage and list serve, in order to alert those concerned that their comments have been evaluated, addressed, and are available for review at those repositories listed within the notice and/or project correspondence.
- During the NEPA process the decisions and reasons are included in the document. We also have a Final Design Hearing to show what's included on the project. With the neighborhood advisory groups, etc. written minutes are included sent to all attendees and a copies are kept in the project files.
- Hearings, environmental reports, and public information centers to present project.
- If it is an issue of high public interest, the decisions are typically communicated through the environmental public involvement process or public meetings. Sometimes letters are sent to concerned citizens if the people affected are a smaller group and the effect is localized.
- If we do at all, it might be at a subsequent public meeting or by a press release.
- In the environmental document (EA or EIS)
- Included in the public meeting(s) for the project.
- Information is available if requested by it is not published to the general public.
- It would be explained to the public at the Public Workshop held during the design process, typically after Preliminary Plans.

- N/A
- Newsletters, websites and other published project information
- Press releases, public meetings, letters
- Primarily documented through hearings, public meetings and the environmental process.
- Public hearings, public meetings, project newsletters
- Public information meetings
- Public Information meetings.
- public meetings
- Public Meetings
- Public meetings either during design or during Early Prelim Engr (EPE) phase for major impact projects.
- Public meetings or website announcements.
- Public meetings without a lot of focus places on “trade-offs”
- Public meetings, individual landowner meetings, press release, etc.
- Public meetings, internet, newsletters, storefronts.
- Public meetings, websites.
- Reader friendly environmental documentation, webpages and project information
- Some projects utilize a public involvement process which allows the general public to review and comment on proposed designs. The Program Manager is made available on all projects to discuss the design selection process.
- Sometimes all the communication between the agency and community is through the city major or a public hearing. If there is a specific issue with lands or propriety, the communication is through the row staff.
- These decisions are communicated to the public through our Public Affairs office and/or via follow-up public meetings.
- This varies; public meetings, meetings with municipal/public officials, work with Public Advisory Committees (if project warrants), revised reports, press releases...
- Through open house community meetings, informational flyers sent to land owners, or through press releases.
- Through public information officers and websites.
- Typically not outside of the usual project documentation, unless there is a specific community impact or interest involving the issue.
- Usually don’t
- Usually part of the design presentation showing avoidance and minimization techniques
- We would discuss in a public informational meeting when presenting the recommended concept
- When it’s judged that communication of a particular issue or outcome is appropriate, it’s typically done through the ongoing public involvement process. If it’s a particularly consequential or large issue, general public affairs communication -- perhaps through the media -- can be necessary.

16. Are there any gaps, problems, or missing components in your STA’s procedures and tools associated with the design selection process relative to evaluating trade-offs?

21 Yes

21 No

Please Explain

- Although there are some guidelines provided to the design engineers, the evaluation of trade-offs usually relies on the engineering judgment of the designer.
- Design criteria are currently being evaluated to improve the guidance designers have available. An improved design exception process with better early involvement has been brainstormed and is in the process of implementation. Better coordination and collaboration is needed to ensure that interests of both internal and external stakeholders are equitably balanced. Better integration of IHSDM and HSM in the process will occur over time. Enhanced tools, support and procedures for assessing risk are continually being developed and deployed.
- Evaluating trade-offs has become a group decision and sometimes the identification of exception can be missed and trade-offs are never discussed.
- I’m sure our process could be improved, but if I knew how, I would be trying to implement them. Political involvement and politically-based design decisions are always a potential problem.
- In some cases, aggressive project schedules require a project to move forward prior to extensively evaluating all trade-offs.
- It has worked well for decades.
- Lack of experienced staff to evaluate alternatives and trade-offs, lack of sufficient funding to make the best choices, and lack of sufficient or standardized documentation.
- Measures of effectiveness for project needs and objectives are currently being incorporated into our Procedures Design Manuals.

- Need to establish more detailed protocol and set up better documentation process. Currently, designers are encouraged to follow a process; however there is no process that is required to be followed unless the issue requires a design exception.
- No formal process exists and there is no central authority to make decisions and maintain documentation leading up to those decisions.
- no set procedures
- Not every tradeoff can be evaluated qualitative, but this is why we have knowledgeable engineers.
- Often environmental impacts are difficult to bring to the same common denominator as capacity and safety
- Our local FHWA reps recently got guidance from Washington that all “should’s” in AASHTO basically equal “shall’s” for design exception purposes. This would put us (and many other states) out of compliance on some of our standard cross sections. Also, our FHWA office requires design exceptions on every criteria mentioned in the 2005 Design Standards Interstate System, not just the 13 controlling criteria. Is this consistent for other states?
- Quantitative Tort Liability Exposure could be better defined
- Since it is informal, it tends to be inconsistent.
- Standard process is good, but for complex or controversial projects, procedures require adjustments of special components.
- The HSM is going to provide assistance with safety impacts of some decisions, but it isn’t yet all-encompassing. Urban street safety is still sketchy, although AASHTO is providing some direction in the upcoming Roadside Design Guide.
- The methods in place seem to be working well. MoDOT enjoys a customer confidence rating of about 95%.
- There is no formal analysis of trade-offs that fall outside of NEPA process...i.e. political commitments/public commitment made after design
- There are no significant gaps, problems or missing components in the Department’s procedures and tools associated with the design selection process relative to evaluating trade-offs that could utilize additional tools or programs. The Department’s intent is clear, however, each and every project’s design criteria and or, commitment’s are evaluated on a case by case process.
- We are always looking for better fact driven information to help us make solid decisions
- We are looking into a more formal use of the safety tradeoffs using the *Highway Safety Manual*
- We do not have PI involvement. There may be others at times as well that our process does not force coordination with.
- We’re trying to get our local FHWA involved in the interstate projects earlier to avoid confusion and delays later in the design process.
- When process in policies are followed, gaps are minimal

17. What strengths or weaknesses exist in your STA’s current design selection process relative to evaluating trade-offs?

Strengths:

- 1. The Context Sensitive Solution approach is all inclusive, collaborative design and decision making process. All stakeholders and users have the opportunity to influence design decisions. 2. Explicit safety consideration. 3. Project level designers are actively involved in making recommendations for trade-offs for approval.
- Above-average design criteria/guidance; good general awareness and understanding of the concept of tradeoffs; reasonable tort liability/immunity statute; written access management guidelines; good proficiency with traffic analytical tools.
- Centralized design resources allow efficient coordination with multiple disciplines. The Program Manager serves as the central point of contact for a project and can evaluate information from multiple sources to determine the most appropriate solution.
- Clearly documented process, design criteria based on context of project area. Safety review committees review all projects.
- Complete documentation in the project history files
- Design selections for more significant/expensive projects are reviewed by Central Office staff and design approval is granted by the Deputy Chief Engineer or the FHWA; standardized report shells provide an efficient way to ‘coach’ design staff regarding what needs to be evaluated, as well as to standardize the documentation provided; public input is sought as a routine courses of business; cost/benefit can be a strong tool.
- Designers are empowered and have a great deal of autonomy in decision making. Flexible standards are in place allowing leaner designs without a formal exception. Management is open to design exception approval.
- detailed crash analysis, itemized impacts, associated to meet criteria, geometric staff review and proposed mitigation measures documented
- Exception (to AASHTO 13 critical elements) documentation. NEPA Process for major projects.
- Flexible--hard to write a policy to cover all, or most, situations.
- Flexible.
- Have a core set of standards the Designers need to follow. The rest leaves flexibility to the Designer.
- In the end we can get environmental permits for the project and we can get the project built.
- It has worked well for decades.
- Knowledgeable professionals in all areas.

- More than one engineer is involved in the trade-offs evaluations
- Multiple reviews by many divisions and agencies provide adequate checks and balances.
- New attention has been focused in this area and approval by Office of Design Director encourages consistency.
- New Project Development and Design Guide
- ODOT has a strong environmental evaluation process with good documentation. Capable reviewers are available to assist and direct decisions.
- One of our strengths is the final approvals are confined to a small experienced group, which provides consistency for the department in the design selection process.
- Our Vermont State Standards provide a lot of flexibility in the decision making associated with design values.
- Process is in place to follow
- Public involvement, commitment to safety, consideration of design and construction process...openness to innovative design and construction techniques.
- Quantitative and Qualitative analysis by multiple stakeholders
- Takes full use of multidisciplinary teams we use
- The decision is transparent and documented
- The Department provides context sensitivity training and design flexibility training for their designers and design managers.
- The DOT, the design offices in particular, is relatively small so decisions can be made quickly during face to face meetings.
- The highest level of the Department's strength and success are mainly achieved by the strong efforts and inputs generated from our most expert employees, as well as, the INDOT'S executive branch leadership for making the best possible choices for the design selection process relative to evaluating trade-offs.
- In 2009, the Indiana Department of Transportation (INDOT) Office of Traffic Safety staff developed the *Local Highway Safety Improvement Program Project Selection Guidance* to support the goals of the State's Strategic Highway Safety Plan (SHSP) for improving safety on local roads. The guide outlines procedures for metropolitan planning organizations (MPOs) and local public agencies (LPAs) to identify high quality safety improvement projects for the use of Highway Safety Improvement Program (HSIP) funds, including:
  - Monitoring network performance relative to traffic safety;
  - Screening locations for safety issues;
  - Identifying feasible crash countermeasures;
  - Analyzing cost effectiveness of alternative investment choices; and
  - Prioritizing needs among candidate projects.

To enhance the guide, INDOT consulted the Indiana MPO Council. Initial feedback indicated that additional information was needed in the document to provide assistance for developing successful HSIP project submissions, particularly for those organizations with limited staff and resources. The issues that needed to be addressed to ensure a successful program included:

- Quality of crash data and restrictions on its accessibility;
- Training for road safety audits;
- Information on analysis tools; and
- Additional technical support for local agencies outside of an MPO area.

As part of its overall strategy to improve local road safety, INDOT and the Indiana MPO Council coordinated with the Federal Highway Administration (FHWA) Office of Safety to organize a peer exchange. The peer exchange would bring together Indiana safety stakeholders to discuss opportunities for MPOs and LPAs to work collaboratively with INDOT to improve safety. As part of the peer-to-peer process, the organizers of the exchange met over several weeks to identify peers that could assist the State with improving local participation in its HSIP program. All the peer agencies that participated in this peer event had experienced some level of success with local HSIP project implementation approaches and techniques. The selected peers included: Mid-Ohio Regional Planning Commission (MORPC), Southeast Michigan Council of Governments (SEMCOG), and Delaware Valley Regional Planning Commission (DVRPC). These peers were selected in order to engage Indiana's MPOs in their HSIP process.

The objectives of the peer exchange were to:

- Discuss highway safety issues and current programs in Indiana;
- Explain the value and purpose of the HSIP process to stakeholders;
- Provide MPOs and LPAs guidance on how to have more input and control over how Indiana's HSIP funds are spent;
- Learn about the noteworthy experiences of peer MPOs with HSIP implementation;
- Create an ongoing dialogue to improve Indiana'a HSIP stakeholders; and
- Identify next steps to improve the HSIP process for local agencies and reduce traffic fatalities.

More than 40 professionals representing 11 MPOs, the Indiana Local Technical Assistance Program (LTAP), and four INDOT district offices participated in the event.

- The project team process involves most or all of the stakeholders.
- We have well defined processes for design exceptions, waivers and deviations.
- We try to utilize national guidelines (AASHTO), as well as, state criteria to provide safe, cost-effective designs. We encourage multi-disciplinary involvement and discussions to determine the best solutions. We interact extensively with our FHWA office to review guidelines and revise them when appropriate.
- We use priority programming and a systematic statewide approach to addressing safety within the state.
- Well documented
- When it works, the documentation level is appropriate to the need. The risks have been discussed and there is a general consensus that the right decision is being made.
- Works well.

Weaknesses:

- 1. There isn't always unanimity among the stakeholders. In certain cases it is difficult to reach a consensus on trade-offs. 2. Environmental trade-offs are not as well quantified and sometimes expose CDOT to regulatory consequences.
- Analysis is sometimes too late in the process
- Does not address that a combination of decisions that meet design standards could still create a poor design.
- Flexibility exists, however, that flexibility is occasionally difficult to apply consistently within our organization.
- Inconsistency.
- Inconsistent from District to District.
- It can be time consuming and a minority opinion can feel unheard.
- It is very challenging to maintain an aggressive project schedule while attempting to coordinate effectively across multiple areas inside and outside of our Agency.
- Lack of assurance that Variation (to state design criteria) documentation is consistent across districts. Documentation for Exceptions to local road standards. Incorporating human factors/driver expectancy into the design for our demographics.
- Lack of communication between offices
- Lack of consistent/predictable funding.
- Lack of experienced staff to develop/evaluate trade-offs; reluctance of Regional staff to accept opinions/expertise of others outside their Region; Current needs far outstrip available resources, so cost makes the decision much of the time; Some costs and benefits are difficult to quantify accurately; the 'vocal public' does not necessarily represent the general public on any given issue, but can evaluate elements of a trade-off until what should be a technical decision becomes a decision influenced by politics.
- lack of training for designers
- Low utilization of IHSDM so far; occasional lapses in early involvement and collaboration with internal stakeholders and approving parties; schedule issues sometimes inhibit constructive processes; social, environmental and modal concerns sometimes under emphasized in decision making; highway safety factors sometimes not well understood.
- More flexible, context-based criteria has been incorporated into our Design Manual. However, we still need to drive the selection of the most flexible, safe, and cost effective criteria by our designers. This is an ongoing culture shift driven by our Central Office.
- No clear cut procedure.
- No follow-up on performance of an expectation.
- No formal decision making and documentation process exists.
- No formal process to recognize and evaluate "all" trade-offs.
- No well established process that is required to be followed (except for design exceptions/design waivers)
- none that are evident
- None.
- None.
- Often decisions are made by persons with little experience without consulting the experts in the field. Project Managers in ODOT have a range of extensive to virtually no experience, and the effects of that can be seen in project results.
- People are creative and seeking the end result with the least effort (they may miss the big picture or the importance of documentation),. Newer tools are good if they add value and don't create a situation where you feed the beast with no perceived benefit to the project.
- Politics can still override any decision making process, no matter how technically sound it may be. Some employees are still uncomfortable with the amount of design freedom they're given and its inherent responsibility.
- Right-of-way issues seem to be the greatest hindrance to effective design. A single landowner can delay projects indefinitely and, if they are politically well placed, they can force undesirable compromises which could result in weakened tort defense.
- Still working out details of what minimums are before a formal design exception to FHWA is required. Some discrepancy with FHWA.

- The Department's hardest weaknesses in respect to the design selection process relative to evaluating trade-offs can be found in:
  - Engineering economic analysis is the classical means for assessing trade-offs in a highway-project. Comparison of road-user benefits against project costs, incorporating money's time value, is the essence of engineering economic analysis. The process historically has been the most widely used project evaluation approach. Subjective influence imparted by the decision maker is restricted. The potential weakness of this traditional form of benefit-cost analysis is that it recognizes only tangible attributes. Non-monetary, external impacts (e.g., social and environmental consequences) receive no direct consideration. However, engineering economic analysis applies well where non-user impact are absent, minimal or identical for all alternatives, and user impacts have a market value.
  - Project strengths and weaknesses are clearly identified by using profiles of the project ratings for each criterion. Thus, strong projects are fully funded, weak projects are not funded and intermediate projects are funded to resolve weakness.
  - Due to the economic downturn, ongoing structural deficit in the nation, and uncertainty regarding the federal transportation funding, it has already become necessary for INDOT to adopt priority-setting criteria and priorities for the remaining funding now available to implement projects in the near term of the long range transportation plan.

INDOT's hardest weakness is the inability to address all of its customer's needs or concerns for the reasons in which described above.

- There is no defined process to evaluate trade-offs
- There may be additional areas that we need to cover with our processes.
- Timely process
- Too cumbersome
- Vocal minorities, or vendors may bring pressure to decide outside acceptable ranges
- When we get newer Project Coordinators and Designers it takes some time to get them trained in the process. Some errors and misses have occurred in the past leading to confusion with our FHWA.

Risk

18. Please define acceptable risk with regards to the use of trade-offs in the design selection process for a typical project.

- Accepting risks may be the most common "default" response in risk management. Mn/DOT eventually needs to determine reporting levels for acceptance to determine who needs to be informed of risks accepted based on the risk event impact and likelihood. Also, if active acceptance is determined to be the strategy of choice, the contingency plans that are put into place need to be captured in such a fashion that the record can be pulled up and applied if the risk event comes to pass. Concerns often surrounded how the Acceptance supports better management decisions. If a high-risk exists within a design choice, and resources are not available to administer an effective design change, the Acceptance response and documentation should support management decisions to focus resources on higher level risks. In the future, the hope is that utilizing an acceptance risk response strategy for a design should depend on a sense of project history and may be subject to the evaluations of leadership, peers and investigating agencies. Because project risks are dynamic, consistency defining a common risk tolerance scale will be a difficult task and dependent on the defining corporate risk tolerance levels.
- Acceptable risk includes a combination of all factors--safety, cost, tort liability, etc. Would no do exception if high risk.
- Acceptable risk is not outlined in a matrix, safety is key and addressed by review of the statewide traffic engineer and resources to determine if risk is acceptable.
- Acceptable risk is where public safety is not jeopardize
- Acceptable risk might be defined as the acceptance of the responsibility of an unexpected event and its consequences because the probability.
- Acceptable risk would be defined as little to no chance the trade-off would cause an increase in the number or severity of accidents.
- An acceptable risk is one that does not compromise safety and meets the needs of the project.
- B/C, IHSDM & projected crash rates associated with exception
- case by case
- Depends on trade-off. I can't define acceptable risk.
- Expert opinion is utilized to evaluate risk. The involved experts determine acceptable risk on a case-by-case basis by seeking input and evaluating data to determine the safety and operational effects to the project.
- For many years, the customary approach to highway project development had been for engineers to gather information, make independent decisions, and then announce and justify their design plans to the public. "Such an approach is no longer feasible in today's professional climate." The public will no longer unquestionably accept project proposals, regardless of how well thought out they are. Rather, it is crucial to involve the public early in the process, and keep them involved, to reach a consensus that is acceptable to everyone.

With the expanding role of public involvement and the push to address concerns beyond engineering in highway projects come added responsibilities and considerations. Today, highway designers face many complex tradeoffs. A quality design requires thoughtful consideration of the needs of a variety of users, and it has to balance cost, safety, and mobility with historical, cultural, and environmental impacts. A quality design is more than simply assembling elements using standard plans or charts from a design manual. Highway engineers and designers need to understand the complex relationships between their design choices and the related risks.

In the past recent years, through conferences, training, and new partnerships, INDOT and its partners have been working to bridge knowledge gaps and enable transportation planners and engineers to design with flexibility and employ context sensitive approaches with greater confidence and regularity.

Understanding this evolving landscape of flexible and context sensitive highway design and how to thrive in it will enable INDOT to build and refine roads and other transportation facilities that not only meet safety and mobility requirements but also help create more livable communities.

The American Association of State Highway and Transportation Officials (AASHTO) built on this philosophy in the 1973 edition of its publication A Policy on Design of Urban Highways and Arterial Streets (also known as the "Red Book"). In the preface, AASHTO encouraged a tailored approach: "Good design will not necessarily result from direct use of the policy values. To form a segment of highway that will be truly efficient and safe in operation, be well fitted to the terrain and other site controls, and be acceptably amenable to the community environment, it must be a carefully tailor-made design for the unique set of conditions along the segment."

Improving or maintaining safety, mobility, and infrastructure conditions."CSS represents a departure from previous project development processes because it broadens the scope of considerations that factor into project decisions, going beyond just engineering principles and practices. As described by FHWA and AASHTO, CSS "is a collaborative, interdisciplinary approach that involves all stakeholders in providing a transportation facility that fits its setting. It is an approach that leads to preserving and enhancing scenic, aesthetic, historic, community, and environmental resources, while transportation engineers and designers are trained to use accepted design criteria throughout project development. Striving to meet those criteria is the primary means by which high-quality roadways are produced. A highway or roadway that reflects full compliance with accepted design criteria decreases the probability that safety or traffic operational problems will develop. Therefore, using design values that lie within typical ranges provides a degree of quality control and a level of risk that transportation agencies consider acceptable.

According to the Project Management Institute, risk is defined as an uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives. In other words, risk is a probability, not a certainty, and the level of consequences, positive or negative, are unknown.

Risks can sometimes yield rewards. That is, a risk could bring about a benefit that would be unachievable without taking that risk. Or a risk might be more tolerable when it is low relative to the potential benefit of the action incurring the risk. The key is to understand and evaluate potential risks associated with a project and weigh the pros and cons to make the best decisions possible.

In an ideal world, agencies would reduce or mitigate all potential risks associated with a project. But in the real world, limited budgets coupled with increased demands on agency staffs necessitate prioritizing where resources will be concentrated. Risk management is the process of identifying, evaluating, prioritizing, and mitigating risks, which guides a coordinated approach to minimize, monitor, and control those risks and their impacts. Part of this process is assessing the probability with which certain risks might occur. To the extent possible, risks should be quantified, both on the basis of their probability and their potential consequences.

Risk management starts early in the project design with identification of the range of potential risks and then selecting the most critical ones to mitigate or plan for. The process continues throughout the project design and requires knowledge of the project-specific risk factors and the exercise of sound professional judgment.

Identifying risks involves analysis of all pertinent issues. Knowledge of a project's geographic, environmental, safety, and traffic conditions and the assumptions underlying the design standards is essential to understanding the risks associated with selecting and applying those standards. Knowledge of human factors--how drivers interact with their vehicles and the road--can help identify potential flaws in the design that might not be readily apparent in the engineering drawings. In many cases, the risks associated with a decision can be mitigated with inclusion or enhancement of other features that could offset the risk.

- For sag vertical curves and narrow shoulders. Using engineering judgment and experience the changes of an accident occurring is very unlikely. We've done this before and provided lighting for the sag curves and emergency services for broken down vehicles in the narrow shoulder areas and haven't experienced any major accidents caused by these tradeoffs.
- History, accident data, are there current problems that need to be mitigated
- I agree with the example above. Also, it should meet prevailing design criteria.
- Matrix
- Mn/DOT started a formal "journey" with Risk Management almost 2 years ago. Mn/DOT believes that Risk Management practices, processes and skills are valuable for creating transparency and stimulating innovation through helping to make more

informed decisions about projects and design choices. Mn/DOT believes that Risk Management is not only a tool and process, but a language and academic field that can drive productive conflict, progress, and management of risks at multiple levels of government. While the vision is to successfully integrate risk management throughout Mn/DOT, implementation has been mindful of both need and demand for the service. Implementation of Risk Management practices throughout Mn/DOT will continue to be a journey. At first, the implementation has focused around program delivery decisions and has branched out as new areas of complex decision-making are recognized. The use of risk-based approaches has already proven to be a rewarding partnering effort at various levels that includes evaluating alternatives for designs for a few major project decisions. Accepting risks may be the most common "default" response in risk management. Mn/DOT eventually needs to determine reporting levels for acceptance to determine who needs to be informed of risks accepted based on the risk event impact and likelihood. Also, if active acceptance is determined to be the strategy of choice, the contingency plans that are put into place need to be captured in such a fashion that the record can be pulled up and applied if the risk event comes to pass. Concerns often surrounded how the Acceptance supports better management decisions. If a high-risk exists within a design choice, and resources are not available to administer an effective design change, the Acceptance response and documentation should support management decisions to focus resources on higher level risks. In the future, the hope is that utilizing an acceptance risk response strategy for a design should depend on a sense of project history and may be subject to the evaluations of leadership, peers and investigating agencies. Because project risks are dynamic, consistency defining a common risk tolerance scale will be a difficult task and dependent on the defining corporate risk tolerance levels.

- Most is Engineering Judgment, or based on guidance material.
- Most risks are based on the crash history of the area and not reducing criteria if no crash history exists.
- N/A
- No real definition of acceptable risk. We normally do the best that we can within the constraints.
- No specific risk thresholds have been established for the agency. Quantitative risk analysis is sometimes used to compare alternative design decisions based on cost. Environmental: Risk is seen as the likelihood that CDOT will incur regulatory fines and other financial harm such as that when partnerships with regulatory agencies are damaged.
- No such formal procedures are typically used.
- Not defined by VDOT. Evaluating risks looks at all factors involved with the design issue.
- Our risk evaluation is informal. Risks associated with safety are our primary concern. This is evaluated through extensive review of crash histories.
- Quantitative and qualitative depending on the issue.
- risk analysis not undertaken, trade-off determined by the maximum safety and facility benefit with reasonable and available budget
- Risk associated with loss of life is evaluated qualitatively
- Risk is assessed subjectively on a project by project basis. A risk is considered acceptable where the impact to safety is minimal.
- Risk is defined by our standards and the Design Committee's review of any exceptions. We do not have a formal risk system.
- Risk is evaluated by evaluating the number and type of crashes at the location attributed to the deficiency or by similar conditions elsewhere for new facilities. That is also combined with professional judgment to reach a conclusion.
- Risk is usually only considered informally so we don't have a definition.
- There are no tools used to help define the acceptable risk. Do not feel comfortable to document an "acceptable" risk on a project.
- Trade-off decisions are often made base on past practice and comparison to similar projects where such trade-offs can be demonstrated to not have had a safety impact.
- Use of qualitative analysis, quantitative analysis and expert opinion to determine the likelihood of an event occurring.
- We are beginning to consciously incorporate risk analysis into our process. In general, acceptable risk is probably the condition you describe: likelihood improbably and severity of consequences minimal.
- We do not measure risk
- We track crashes with a Safety Investment Program (SIP) Category. On category 1-2 projects more risk is accepted because the conditions have not increased in the number of crashes.
- We use risk matrices and evaluate risk on all projects on a case by case basis.

19. Please define unacceptable risk with regards to the use of trade-offs in the design selection process for a typical project.

- A risk would be considered unacceptable if there is a significant impact to safety considerations.
- An unacceptable risk is one that does create a higher risk or perceived risk uncertainty with minimal perceived benefit.
- case by case
- Depends on trade-off. I can't define acceptable risk.
- Expert opinion is utilized to evaluate risk. Similar to number 18, the involved experts determine unacceptable risk on a case-by-case basis by utilizing all available input and data to determine the safety and operational effects to the project.

- For vertical clearance. Using engineering judgment and experience the chances of an accident occurring is unlikely, if there is an accident there are great risks involved. The interstate can be shut down for a long time, which can in itself cause rear end collisions to occur. The possibility of fatalities can increase dramatically.
- Gross negligence is unacceptable. All design decisions are to be based on sound engineering judgment. Decisions are to be documented.
- I agree with the example stated above, especially with regard to safety and operations and durability/sustainability of the project.
- If a crash history exists, this project area must be corrected with appropriate Design Criteria.
- In the future, we hope that after completing a design risk analysis and identifying strategies to minimize those risks, the residual risk can be compared to the corporate risk tolerance (for example safety risk). If that level of residual risk cannot be tolerated, additional resources and design strategies will be necessary. After Mn/DOT becomes more and more sophisticated with risk management, the designer can explore reducing resources from design activities that manage low risks, and engage in a process to focus on high risk levels before taking design action to manage risks to a tolerable level. In the future, we hope to see each ongoing design strategy requiring attention in order to ensure that risk levels remain acceptable. All threatening risk events can never be eliminated. While perfection is certainly a desirable goal, no risks or perfection may not be worth the cost or effort to achieve and maintain (akin to the "law of diminishing returns."). However, there is a risk level that a designer should identify as unacceptable. Management's challenge is to define a risk threshold levels throughout Mn/DOT that is important to maintain.
- It is the responsibility of project managers to determine whether arguments for or against flexibility in establishing acceptable or unacceptable risk levels are sufficiently compelling for use in their jurisdiction. If calculated risk exceeds a numerical limit then project managers must determine if this exceeding represents unacceptable risk.

  Another important aspect is the different interest of each stakeholder may prone to be conflicted with the interest of each other. What may be perceived as unacceptable risk by one individual and or, group of stakeholders may be acceptable in the view of the others. In practice, the numerical results of systematic, rigorous, and transparent risk analyses are used as inputs into a risk management process that does not have the same performance attributes of the risk assessment process. The risk management process often transforms the definition of acceptable or unacceptable risk in a non-transparent manner resulting in inefficient multi-criteria decision-making and public confusion as to what constitutes acceptable or unacceptable risk.

  If the cost of possible mitigations and or, recovery process cost required for a typical project which can result in failure surpass its benefits, then it would be fair to say that "the risk taken for this project is of an unacceptable risk."

- Matrix
- Most is Engineering Judgment, or based on guidance material.
- Most unacceptable risks are related to situations that lead to budget creep and schedule delays based on design decisions.
- N/A
- No real matrix analysis. More of an agreement of several knowledgeable representatives on the PMT.
- No specific risk thresholds have been established for the agency. We are focused on comparing design alternatives within constrains of the available budgets.
- No such formal definition exists
- Purpose and Need
- Quantitative and qualitative depending on the issue.
- Reducing safety to deliver a project within the programmed cost is unacceptable
- Reduction in safety and the likelihood of increase of crashes would be unacceptable regardless of schedule or budget creep. Mitigative measures would control those factors.
- risk analysis not undertaken, trade-off determined by the maximum safety and facility benefit with reasonable and available budget
- Risk deemed as unacceptable during the safety review mentioned above as well any time that there is a high likelihood of any item that would threaten the scope, schedule or budget of the project.
- Risk is usually only considered informally so we don't have a definition.
- SIP category 3-5 projects have an increase number of crashes and thus reduced standards could increase already high number of crashes.
- The opposite of above.
- There is no value placed on lives/safety. Budget and schedule are not nearly as important as safety and would not be considered unreasonable to change.
- Unacceptable risk could be defined as the consequences of trade-off decisions being unsafe and non-durable projects.
- Unacceptable risk for this agency generally involves reducing safety of a facility (perceived or data-driven), or making choices that would delay a project out of a fiscal year, or would increase costs to more than 110% of budget.
- Unacceptable risk might be defined as the event that has been rejected or ausided to occur because its consequences are considered a hazard to human life or threat to reach a desired goal and project success

- Unacceptable risk would be any trade-off that resulted in an anticipated hazardous condition on the roadway. We have not utilized risk analysis to assess schedule and budget creep. We have not addressed this well to date. Consequently, we have not defined acceptable/unacceptable risk for these areas.
- Unacceptable risk would be defined as a trade-off that would cause an increase in the number or severity of accidents.
- Unacceptable risk would be one of two outcomes in the previous response.
- We use risk matrices and evaluate risk on all projects on a case by case basis.

20. Does your STA have risk prediction tools or techniques to assist in balancing competing interests as part of the design process?

12 Yes

30 No

If yes, please describe the tool/technique and how it fits into the project development process.

- CRA/CEVP/self-modeling for cost and schedule Roadside safety analysis procedures
- Draft *Highway Safety Manual*, Roadside Safety Analysis Program.
- IHSDM, Roadside Safety Analysis Program (not currently in use)
- IHSDM, RSAP, Value Engineering, Accident History
- INDOT is currently using Accident Reduction Factors developed by the State of Missouri. These factors are shown in the *Indiana Design Manual* Section 50-2.03(05); see figure 50-2G. The ARFs are applied to the total number of accidents, regardless of the number of people or vehicles involved, when calculating accident reduction factors and hence limiting amount of risk that may be apparent and or predicted.

  INDOT also collects work zone crash data, queue and delay measurements and evaluates general work zone conditions. The crash data is obtained from the statewide Automated Reporting Information Exchange System (ARIES). The data is collected for the construction period and compared to a non-construction period at the location of the work. A comparison of the two sets of data is used to formulate conclusions about work zone safety and needs for improvement to policy and standards and is used to identify potential risks for incidents, travel delays or increased congestion.

  Projects that have the greatest impact to travelers will involve the Public Safety Operations (PSO) Division of the Traffic Management Business Unit to provide assistance in identifying innovative methods of risk avoidance and consider methods to reduce or avoid traffic incidents during construction.

- Most of the risk assessment has been built into the standards.
- On projects larger than $100 million we require a risk analysis process be performed on it. These are usually completed by consultants, since there is no one available with expertise currently. We are currently looking at where and what we should be using.
- Safety analysis and accident rate comparisons.
- To deal with uncertainty we use Quantitative Risk Analysis decision trees in concert with sensitivity analysis of cost/benefits. Environmental: Unacceptable risk would be non-compliance with the Endangered Species Act or Clean Water Act, the later has already seen Notice of Violations and Consent Orders at CDOT. Additional violations will affect not only the project in question, but the repercussions affect CDOT as a whole.
- Value Analysis Study
- We do not have a quantitative risk matrix but risk is discussed at each milestone with expert opinions from key individuals and risk management also looks at each project.
- We require that all non-standard features (i.e. proposed critical design elements that do not meet design criteria standards) be justified in a standardized format that includes an accident, benefit/cost comparison, anticipated effects and proposed mitigation. This process is required prior to and approved at the time of design approval.
- While the vision is to successfully integrate risk management throughout Mn/DOT, implementation has been mindful of both need and demand for the service. Steps are currently ongoing to implement Risk Management processes throughout project delivery. Are initial goal is to start developing living risk registers throughout the state for major projects and continue to deliver training for folks involved in project level risk management. Major steps in a Risk Management Process include: 1. Gather Information (Performance Measures, data, etc.); 2. Create Vision or Context or project objective statement; 3. Brainstorm Risk and create specific risk statements; 4. Forecast probability of risk statement occurring; 5. Judge Impact, assuming the event occurs. Based on Project purpose and need or Vision of Success; 6. Prioritize Risk Statements by the product of likelihood and impact; 7. Develop Risk Response Strategies for High Level Risks (Designs); 8. Judge Effectiveness of Strategies, upon how strategy mitigates impact or probability; 9. Assign Accountability; 10. Assign Rough Cost; 11. Monitoring and Lessons Learned; 12. After new information or change, updating the risk register at Step 1 again.

21. If your STA does have risk prediction tools or techniques, are they

1 Quantitative

3 Qualitative

11 Both

25 None

Tools and Training

22. Does your STA have any specific tools to assist designers in evaluating trade-offs in the design selection process?

21 Yes

21 No

If yes, please describe the tools available.

- Guidance on design exception justification in Road Design Manual Chapter 2; 2. Strategic risk management tools and resources, including: a risk management process expert and facilitator; Risk Management classes; facilitation techniques video clips; an E-learning class in Risk Management basics; templates for Risk Registers; some guidance.
- Crash analysis in relation to geometric elements at site specific locations
- Design Policy manual addresses typical tradeoffs. There is also a formalized design process. Internal Designs have a formal QA/QC process.
- do not have anything sophisticated such as the Australian Quantum software
- Draft *Highway Safety Manual*, Roadside Safety Analysis Program.
- *Highway Safety Manual*
- IHSDM, RSAP, Value Engineering, Accident History
- INDOT applies the Roadway Safety Analysis Program (RSAP) in order to assess the cost-effectiveness of a design in respect to the following modules:
  - Encroachment Module,
  - Crash Prediction Module (this software implements Part C of the *Highway Safety Manual* (HSM)),
  - Severity Prediction Module, and
  - Benefit/Cost Analysis Module.
- Life cycle cost and value engineering.
- Mentorship and training courses
- Minimum Design Standards, AASHTO Policy (*Green Book), Roadside Design Guide*, etc.
- NEPA Guidelines
- Our design exception process provides guidance for evaluating design decisions which fall outside of documented guidelines.
- Our manual of instruction does address this issue as well as other resources dealing with strategies to properly mitigate exceptions to the STA standards.
- Qualitative and quantitative depending on the issue.
- Research, NCHRP, IHSDM, etc...
- Safety Assessment Process deals with safety explicitly and is institutionalized at CDOT.
- There is flexibility built into our design criteria which is based on project context, beyond traditional functional classification.
- Value Analysis Study
- VDOT utilizes a Context Sensitive Design Handbook and the FHWA publication 'Mitigation Strategies for Design Exceptions.'
- We have a design manual which discusses conditions under which tradeoffs should not be made and references the AASHTO A Guide for Achieving Flexibility in Highway Design, 2004 document, a justification of NS features form that provides guidance on the areas to consider when proposing to incorporate a NS element.
- WSDOT Design Manual

23. Does your STA have any training to assist designers in evaluating trade-offs in the design selection process?

18 Yes

23 No

If yes, please describe the training available.

- 3 day geometric/design exception class
- But we are developing some especially when it comes to Exceptions.
- CDOT has the Transportation Engineering Training Academy program. It is part of the Project Development training program.
- Context Sensitivity training -- 2 day workshop providing case studies and evaluation tools to be utilized by the designer. Context Sensitive Handbook.
- Design courses available on different issues such as safety, environmental issues, cost estimate development, etc...
- Design Standards Training, Mentoring, etc.
- Design training is offered on a regular basis to enhance the ability for design staff to make an appropriate decision. By offering a diverse cross section of engineering training, we expose our design staff to information and practices which can be used and to create and evaluate design decisions.
- Designers are required to participate in training in Geometric Design, Roadside Design, Context Sensitive Design, etc., all of which builds their knowledge of appropriate design standards and how to balance standards when necessary.
- Have had Context Sensitive Solutions training courses
- Mentorship and training courses
- More training is always helpful. Budget and staff in constraints have made this challenging. Distributed low cost training, such as webinars, are becoming more popular.
- NEPA Training for all Planning Staff
- Not specific training but the basic training in all technical specialties gives the designers the ability to make judgment about the relative merits of making trade-offs
- Ongoing training is not provided although it is addressed with some ad hoc training during conferences or quarterly meetings.
- Risk Analysis training and Value Analysis training
- Risk management classes (mentioned above under Question 22) and advanced design flexibility curriculum wherein tradeoffs are discussed
- Roadside Design, Geometric Design, Conference, PM training.
- The list described below represents some of the training courses and or webinars available, for which the in-house designers and or, engineers were required to attend in 2010: Design Flexibility Webinar, *Highway Safety Manual* (HSM), Culvert Rehabilitation Techniques, Urban and Suburban Intersection (HSM), LRFD Foundation Review, AASHTO Section 12.12 LRFD, Designing Streets for Pedestrian Safety, Context Sensitive Design…etc.
- Training available through FHWA Courses if necessary and informal training by other staff.
- Training has been provided on Safety Reviews as well as the application of context based design criteria through our Smart Transportation Guidebook.
- training is available in the area of context-sensitive design, and roadside safety. Self-training in electronic format is available for geometric design.
- WSDOT project development training and University training courses.

Your Experience

24. Has your agency developed any specific performance goals regarding the evaluation of trade-offs in the design selection process?

5 Yes

37 No

If yes, please provide the goals developed.

- Between FY 2008 and FY 2010, INDOT reduced its operating expenses by $61.5 million (14.9%). This performance is especially impressive when considering that transportation investments-both new construction and preservation initiatives-are achieving record levels, in part due to the Major Moves program and the American Recovery and Reinvestment Act. Specifically, during FY 2009 and FY 2010, INDOT committed nearly $3 billion in fund to improve the State's Transportation infrastructure. This, on average, is 39% greater than the prior period investment.
  - In 2006, Indiana partnered with the Indiana Toll Road Concession Company to lease the toll road for a period of 75 years in exchange for $3.8 billion. The proceeds from this collaboration help fund the Major Moves highway improvement program (and saves INDOT the approximately $35 million a year it was spending to maintain the toll road). INDOT committed $488.1 million of the toll road lease proceeds in FY 2010. This partnership has also become a model for other States.
  - INDOT actively participates in the continuing, comprehensive and collaborative planning process with 14 Metropolitan Planning Organizations (MPO's) throughout the State. Represented by MPOs, each of these 14 areas have populations over 200.000 (Group I) or 50,000 (Group II). MPOs assist in making the community planning process in urbanized areas a collaborative and coordinated effort among the many local government agencies within their planning areas. With approxi-

mately $200 million in federal-aid funding available every year, the MPOs play a large part in Indiana's metropolitan transportation picture.
  - As part of the department's efforts to increase knowledge about the Local Public Agency (LPA) Process and to better equip local agencies to complete a federal-aid project, the department has developed a local Guidance Document (LGD). The LGD provides information and resources on the necessary steps to complete a federal-aid project in accordance with all federal regulations.
  - INDOT is making the best use of its funding by cutting costs and increasing productivity. Despite a more severe winter in FY 2010, person hours devoted to weather were decreased by 23%, and overtime hours decreased by 21%, resulting in a total decreased weather hour cost of 13%.
- Crash reduction goals and right-sizing cost savings goals
- E.g., for bridges, rehabilitation work must provide a certain life at an acceptable condition rating to justify the cost of rehab.
- Make our transportation network "safer," make our infrastructure "last longer", make our organization a place that "works well", make our organization a "great place" to work
- Target Zero under safety

25. Can you provide an example(s) of successful implementation of trade-offs in the design selection process.

- 1. The US 285 EA project received an award for CSS. The design implemented some variations to a design based entirely on safety and mobility. This was documented in a paper presented to TRB as part of an NCHRP study currently being conducted. 2. US 36 -- Responded to public input relative to managed lane separation and shoulder design to reduce the projects footprint and impacts. 3. 6th and Wadsworth -- Trade off on superelevation on a loop ramp to reduce ROW impacts. 4. Parker/225 -- Replaced flyovers with left turn lanes.
- Downtown Chaska (Trunk Highway 41, still in planning/design): Tradeoffs were explored between competing cross sectional width elements to arrive at an efficient and safe cross section and equitable balance. This included design exceptions for lane width and shoulder width. Included in the consideration was the need for a wide raised median for traffic calming and pedestrian refuge. Additionally, non-warranted traffic signals are included in the proposal to aid in safe pedestrian crossings. This was negotiated with the local city, who agreed to make every other cross street a right-in/right-out condition in exchange for the non-warranted signals. This project is an example of tradeoffs in competing design elements as well as functional, operational and safety elements. Although non-warranted signals are typically considered dubious from the standpoint of safety, overall expected safety is improved due to the ped safety improvement and the leveraged access restriction.
- I-235 project had areas of tight ROW in an urban setting. There was not enough room in one area to provide required shoulder width without purchasing massive ROW or building complex retaining walls. Interstate standards would have required a 12' median side shoulder in this area and there was only room for 6'. The shoulders were built at 8' and the lanes were reduced to 11'. It was considered safer to have space for a car to get off so the shoulder was built at 8' and the lanes were narrowed to 11'.
- In general, eliminate parabolic cross-section in a horizontal curve to provide straight line superelevation, particularly on high side with 3R project, but possibly not to full design criteria while avoiding ROW acquisition and addressing crash concerns
- INDOT pavement preservation initiative was implemented that adds life to existing lanes and decreases construction costs. The life of equipment and other assets has been extended through repairs and refurbishment, and contracts have been secured to purchase 71 pieces of heavy machinery for $1.2 million below cost estimates.
- In FY 2008, INDOT added a new chapter to its design manual as a guide. This guide regarding the design of Non-motorized-Vehicle-Use Facility provides a source of guidance to implement the Indiana Trails, Greenways, and Bikeway plan. A safe, convenient, and well-designed facility is essential to encourage public use. This Section (51-7.0) provides information on the development of facilities to enhance and encourage safe non-motorized-vehicle, pedestrian, and bicycle travel. A shared-use path facility is required to comply with the American with Disability Act of 1990 (ADA) so that it is functional for all users, both with and without disabilities. A non-motorized-vehicle-use facility provides a much safer pathway for the non-motorized multiple users comparing to other motorized pathways.
- MD5 Leonourdtown--Heavy movement of horse and buggy on mainline of state highway. Revised typical section of roadway to accommodate horse and buggy safely with cars.
- MoDOT has undertaken an enormous bridge replacement program on a greatly reduced budget. Some of the trade-offs involved reasonable roadside hardware considerations such as delineation only option for bridge ends on very low-volume roads. There were hydraulic trade-offs such as small increases in upstream rise where appropriate. Deck widths were decreased, employing narrower shoulders on minor road structures. Due to these and numerous other considerations, 800 bridges will be replaced or undergo major rehabilitation within three years at a fraction of the cost of replacing the same number, within the same timespan, by conventional methods.
- n/a
- Narrow median through a wetland to reduce the R/W footprint
- No
- No

- No specific projects.
- No.
- No.
- No.
- On the US 95 widening project in Las Vegas from I-15 to Summerline we needed to add additional travel lanes, but the roadway was located in massive cut section. We couldn't achieve the shoulder on the median or outside of the travel lanes, so no shoulders were included on the project. This was allowed because it was considered an interim project until the massive project was advertised 5 years down the road. We provided a 24 hour emergency resource van for the five years to remove broken down vehicles quickly and to assist on accidents. We continue to have the 24 hour emergency resource van because of the positive feedback from the public.
- Our design criteria for 3R work on non-NHS arterials, collectors, and local roads use of existing elements with design speeds less than the posted speed. We call these "tolerable controls."
- Point Marion Bridge Project, Bridge type selected based on environmental factors.
- Public involvement frequently affects our design development. There have been a number of projects where the public has weighed in to say they'd prefer a "lesser" alternative with fewer impacts, than one meeting all the standards. Not being involved with the specific projects, it's hard to discuss the specifics in detail.
- Shoulder width on freeways
- Yes, many potential "trade-offs" have been implemented in the area of lane/shoulder width, etc... Not sure that any of the projects would be appropriate for a case study but would be willing to attempt.
- Yes. We are in the midst of studying our state design criteria. During the initial review we analyzed two projects in the Tampa are where trade-offs were necessary to expand 2 lane rural roads into six lane suburban roads with minimal ROW acquisition.

Would you be willing to allow this project to be used as a potential case study for the synthesis, which would require identifying your agency affiliation with the case study results only?

8 Yes

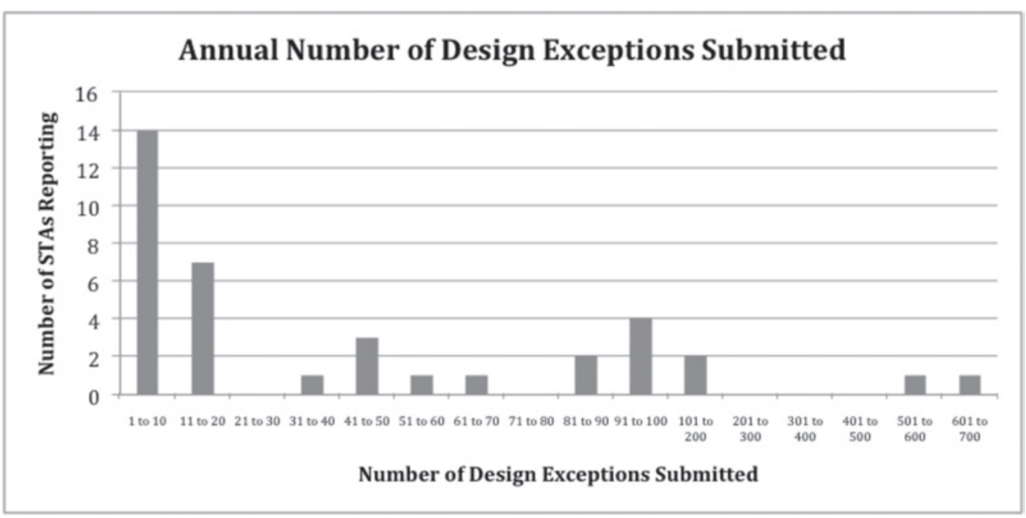
22 No

Design Exception Process

26. How many design exceptions does your agency process in a typical year?

Annual number of design exceptions

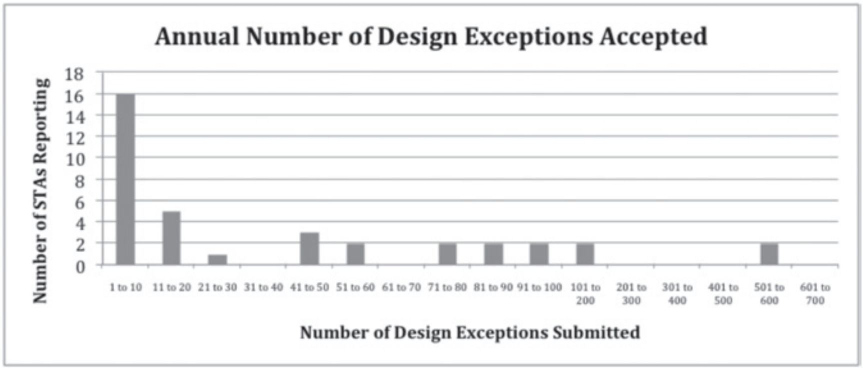
Range 1 to 700 with a mean of 74



27. How many of these design exceptions are approved in a typical year?

Number of approved design exceptions

Range 1 to 600 with a mean of 65



28. Has the advent of context-sensitive design, context-sensitive solutions, or design flexibility increased the number of design exceptions processed by your agency in a typical year?

7 Increased

4 Decreased

28 No Change

Please explain.

- Although it is appropriate to have flexibility in some design standards our commitment as highway designers is to comply with full or at least minimum required standards.
- Although the term Context Sensitive Design has been discussed with much more frequency in the last several years, the concept has been around for some time. The principles of CSD have been applied for number of years, therefore we have not seen an increase in design exceptions from it.
- Although we have a new Project Development and Design Guide which embraces the CSS and design flexibility principles, we basically were always doing projects in a context sensitive way.
- CDOT's design criteria is the same as AASHTO's which allows for Design Flexibility and CDOT generally select design values that are at least the minimum value per AASHTO publications.
- Context sensitive solutions have been successfully implemented within our Agency and the resulting design decisions do not always translate into design exceptions. We are generally able to implement shareholder input without varying from our accepted guidelines and practices.
- CSD has tended to raise awareness among design staff of opportunities for design flexibility and the need to balance design factors versus each other and versus social and environmental factors. The increased awareness has led designers toward sub-standard but appropriate solutions and reduced inhibitions about seeking design exception approval.
- CSS considered but not with compromise to geometric design criteria
- Designers are encouraged to look outside the box and look for solutions that better reflects the stakeholders' interests.
- FHWA rarely considers CSD as adequate standalone justification for design exceptions. CSD is frequently used for the SHA on an informal process.
- Increased design flexibility is being implemented.
- More flexible design criteria have reduced the number of features that require Design Exceptions.
- Our VT State Standards were implemented in 1997, there were many more exceptions then that there are today. This is due mostly to a higher comfort level with implementing the flexibility in those standards
- The advent of CSD/S, flexibility in design has raised awareness that the best project may involve some combinations of features that do not all meet standard design criteria, but which allow a project to be incorporated into the surrounding community in a way that preserves or creates a facility that is both safe and meets the needs of the users.
- The Department's CSS policy and procedures are still being formulated, so CSS has not yet had a great impact on our process.
- The philosophy of picking appropriate standards and designing to those standards has been prevalent at the Department. This philosophy is in concert with context sensitive designs. If the standards are appropriate, the need for a design exception is less.

- To date we haven't had an increase in exceptions for true context sensitive issues -- we have had an increase in design exceptions to reduce right-of-way impacts, but the context is almost exclusively cost based.
- We have incorporated these into our process years ago.
- We have practiced the principles of CSS for a long time and meet prevailing criteria
- With more flexibility built into the standards, the need to seek exception has greatly reduced.

29. For which type of design exceptions do you typically receive the most requests? Please rank the top 3 by indicating the greatest number of requests as 1, second as 2, and third as 3.

Greatest Number of Requests

Design Speed	1
Lane Width	2
Shoulder Width	18
Bridge Width	1
Structural Capacity	0
Horizontal Alignment	5
Vertical Alignment	4
Grade	1
Stopping Sight Distance	3
Cross Slope	1
Superelevation	1
Vertical Clearance	0
Horizontal Clearance	1

Second Greatest Number of Requests

Design Speed	2
Lane Width	5
Shoulder Width	8
Bridge Width	2
Structural Capacity	0
Horizontal Alignment	7
Vertical Alignment	3
Grade	3
Stopping Sight Distance	0
Cross Slope	2
Superelevation	2
Vertical Clearance	3
Horizontal Clearance	1

Third Greatest Number of Requests

Design Speed	2
Lane Width	3
Shoulder Width	8
Bridge Width	1
Structural Capacity	0
Horizontal Alignment	4
Vertical Alignment	8
Grade	4
Stopping Sight Distance	1
Cross Slope	0
Superelevation	2
Vertical Clearance	3
Horizontal Clearance	2

All Responses

Design Speed	5
Lane Width	10
Shoulder Width	34
Bridge Width	4
Structural Capacity	0
Horizontal Alignment	16
Vertical Alignment	15
Grade	8
Stopping Sight Distance	4
Cross Slope	3
Superelevation	5
Vertical Clearance	6
Horizontal Clearance	4

30. Please indicate on a scale of 1 to 10 how willing your agency typically is to consider a design exception for a particular controlling criteria, with 10 being very likely to consider a design exception for the listed criteria and 1 being not likely to consider a design exception for the listed criteria.

Design Speed – Average 3.9

10	Not Likely 1
5	2
8	3
1	4
3	5
3	6
3	7
4	8
1	9
1	10 Very Likely

Lane Width – Average 6.2

0	Not Likely 1
2	2
4	3
3	4
5	5
5	6
4	7
13	8
2	9
1	10 Very Likely

Shoulder Width – Average 7.7

0	Not Likely 1
0	2
1	3
1	4
4	5
2	6
9	7
4	8
12	9
6	10 Very Likely

Bridge Width – Average 5.5

1	Not Likely 1
4	2
5	3
4	4
6	5
3	6
6	7
6	8
2	9
2	10 Very Likely

Structural Capacity – Average 2.0

24	Not Likely 1
5	2
5	3
1	4
2	5
0	6
2	7
0	8
0	9
0	10 Very Likely

Horizontal Alignment – Average 5.7

1	Not Likely 1
4	2
3	3
2	4
4	5
10	6
8	7
3	8
3	9
1	10 Very Likely

Vertical Alignment – Average 6.4

2	Not Likely 1
1	2
2	3
3	4
4	5
6	6
6	7
6	8
7	9
2	10 Very Likely

Grade – Average 6.1

0	Not Likely 1
2	2
3	3
4	4
5	5
9	6
6	7
4	8
4	9
2	10 Very Likely

Stopping Sight Distance – Average 4.5

3	Not Likely 1
4	2
11	3
3	4
6	5
2	6
6	7
3	8
0	9
1	10 Very Likely

Cross Slope – Average 5.4

1	Not Likely 1
5	2
2	3
5	4
4	5
8	6
7	7
5	8
2	9
0	10 Very Likely

Superelevation – Average 5.5

1	Not Likely 1
4	2
2	3
3	4
7	5
7	6
8	7
7	8
0	9
0	10 Very Likely

Vertical Clearance – Average 4.5

6	Not Likely 1
5	2
5	3
4	4
5	5
1	6
8	7
3	8
1	9
1	10 Very Likely

Horizontal Clearance – Average 5.2

3	Not Likely 1
4	2
3	3
4	4
6	5
4	6
8	7
6	8
1	9
0	10 Very Likely

31. For each of the controlling criteria listed, is your STA's criteria for new construction and reconstruction higher than AASHTO's (check one for each)?

	STA Criteria Greater Than AASHTO	STA Criteria The Same as AASHTO	STA Criteria Lower Than AASHTO
Design Speed	6	32	1
Lane Width	6	33	1
Shoulder Width	5	33	1
Bridge Width	2	35	1
Structural Capacity	2	36	0
Horizontal Alignment	1	38	0
Vertical Alignment	2	38	0
Grade	2	38	0
Stopping Sight Distance	4	36	0
Cross Slope	5	35	0
Superelevation	3	37	0
Vertical Clearance	11	29	0
Horizontal Clearance	5	35	0

32. Please select the most common and next most common trade-offs associated with a design exception for the corresponding criteria:

Design Speed

Most Common Trade-Off

Access Management	1
Cost	3
Environmental Issue	2
Historic Impact	1
Human Factors/Driver Expectancy	0
Operational Efficiency	3
Right-of-Way Availability	7
Safety	10
Schedule	0
Social Concerns	2
Tort Liability Exposure	0

Next Most Common Trade-Off

Access Management	1
Cost	8
Environmental Issue	4
Historic Impact	1
Human Factors/Driver Expectancy	6
Operational Efficiency	3
Right-of-Way Availability	2
Safety	1
Schedule	0
Social Concerns	2
Tort Liability Exposure	0

All Responses

Access Management	2
Cost	11
Environmental Issue	6
Historic Impact	2
Human Factors/Driver Expectancy	6
Operational Efficiency	6
Right-of-Way Availability	9
Safety	11
Schedule	0
Social Concerns	4
Tort Liability Exposure	0

Lane Width

Most Common Trade-Off

Access Management	0
Cost	7
Environmental Issue	3
Historic Impact	2
Human Factors/Driver Expectancy	1
Operational Efficiency	2
Right-of-Way Availability	16
Safety	5
Schedule	0
Social Concerns	1
Tort Liability Exposure	1

Next Most Common Trade-Off

Access Management	1
Cost	9
Environmental Issue	5
Historic Impact	1
Human Factors/Driver Expectancy	6
Operational Efficiency	2
Right-of-Way Availability	10
Safety	2
Schedule	1
Social Concerns	1
Tort Liability Exposure	0

All Responses

Access Management	1
Cost	16
Environmental Issue	8
Historic Impact	3
Human Factors/Driver Expectancy	7
Operational Efficiency	4
Right-of-Way Availability	26
Safety	7
Schedule	1
Social Concerns	2
Tort Liability Exposure	1

Shoulder Width

Most Common Trade-Off

Access Management	0
Cost	10
Environmental Issue	4
Historic Impact	1
Human Factors/Driver Expectancy	2
Operational Efficiency	0
Right-of-Way Availability	16
Safety	5
Schedule	0
Social Concerns	0
Tort Liability Exposure	0

Next Most Common Trade-Off

Access Management	0
Cost	8
Environmental Issue	7
Historic Impact	1
Human Factors/Driver Expectancy	2
Operational Efficiency	1
Right-of-Way Availability	11
Safety	6
Schedule	1
Social Concerns	1
Tort Liability Exposure	0

All Responses

Access Management	0
Cost	18
Environmental Issue	11
Historic Impact	2
Human Factors/Driver Expectancy	4
Operational Efficiency	1
Right-of-Way Availability	27
Safety	11
Schedule	1
Social Concerns	1
Tort Liability Exposure	0

Bridge Width

Most Common Trade-Off

Access Management	0
Cost	24
Environmental Issue	2
Historic Impact	3
Human Factors/Driver Expectancy	0
Operational Efficiency	0
Right-of-Way Availability	1
Safety	7
Schedule	0
Social Concerns	0
Tort Liability Exposure	0

Next Most Common Trade-Off

Access Management	0
Cost	8
Environmental Issue	8
Historic Impact	1
Human Factors/Driver Expectancy	2
Operational Efficiency	3
Right-of-Way Availability	6
Safety	6
Schedule	1
Social Concerns	2
Tort Liability Exposure	0

All Responses

Access Management	0
Cost	32
Environmental Issue	10
Historic Impact	4
Human Factors/Driver Expectancy	2
Operational Efficiency	3
Right-of-Way Availability	7
Safety	13
Schedule	1
Social Concerns	2
Tort Liability Exposure	0

Structural Capacity

Most Common Trade-Off

Access Management	1
Cost	10
Environmental Issue	2
Historic Impact	1
Human Factors/Driver Expectancy	0
Operational Efficiency	0
Right-of-Way Availability	1
Safety	10
Schedule	1
Social Concerns	0
Tort Liability Exposure	0

Next Most Common Trade-Off

Access Management	0
Cost	8
Environmental Issue	3
Historic Impact	2
Human Factors/Driver Expectancy	0
Operational Efficiency	4
Right-of-Way Availability	1
Safety	2
Schedule	2
Social Concerns	1
Tort Liability Exposure	3

All Responses

Access Management	1
Cost	18
Environmental Issue	5
Historic Impact	3
Human Factors/Driver Expectancy	0
Operational Efficiency	4
Right-of-Way Availability	2
Safety	12
Schedule	3
Social Concerns	1
Tort Liability Exposure	3

Horizontal Alignment

Most Common Trade-Off

Access Management	0
Cost	10
Environmental Issue	4
Historic Impact	1
Human Factors/Driver Expectancy	0
Operational Efficiency	2
Right-of-Way Availability	14
Safety	5
Schedule	0
Social Concerns	1
Tort Liability Exposure	0

Next Most Common Trade-Off

Access Management	0
Cost	6
Environmental Issue	4
Historic Impact	1
Human Factors/Driver Expectancy	4
Operational Efficiency	0
Right-of-Way Availability	7
Safety	11
Schedule	1
Social Concerns	2
Tort Liability Exposure	1

All Responses

Access Management	0
Cost	16
Environmental Issue	8
Historic Impact	2
Human Factors/Driver Expectancy	4
Operational Efficiency	2
Right-of-Way Availability	21
Safety	16
Schedule	1
Social Concerns	3
Tort Liability Exposure	0

Vertical Alignment

Most Common Trade-Off

Access Management	0
Cost	14
Environmental Issue	3
Historic Impact	1
Human Factors/Driver Expectancy	0
Operational Efficiency	2
Right-of-Way Availability	8
Safety	8
Schedule	0
Social Concerns	0
Tort Liability Exposure	0

Next Most Common Trade-Off

Access Management	0
Cost	5
Environmental Issue	6
Historic Impact	1
Human Factors/Driver Expectancy	8
Operational Efficiency	0
Right-of-Way Availability	4
Safety	10
Schedule	1
Social Concerns	1
Tort Liability Exposure	0

All Responses

Access Management	0
Cost	19
Environmental Issue	9
Historic Impact	2
Human Factors/Driver Expectancy	8
Operational Efficiency	2
Right-of-Way Availability	12
Safety	18
Schedule	1
Social Concerns	1
Tort Liability Exposure	0

Grade

Most Common Trade-Off

Access Management	0
Cost	16
Environmental Issue	3
Historic Impact	2
Human Factors/Driver Expectancy	2
Operational Efficiency	4
Right-of-Way Availability	4
Safety	6
Schedule	0
Social Concerns	0
Tort Liability Exposure	0

Next Most Common Trade-Off

Access Management	0
Cost	7
Environmental Issue	5
Historic Impact	1
Human Factors/Driver Expectancy	4
Operational Efficiency	3
Right-of-Way Availability	8
Safety	7
Schedule	1
Social Concerns	1
Tort Liability Exposure	0

All Responses

Access Management	0
Cost	23
Environmental Issue	8
Historic Impact	3
Human Factors/Driver Expectancy	6
Operational Efficiency	7
Right-of-Way Availability	12
Safety	13
Schedule	1
Social Concerns	1
Tort Liability Exposure	0

Stopping Sight Distance

Most Common Trade-Off

Access Management	0
Cost	7
Environmental Issue	1
Historic Impact	2
Human Factors/Driver Expectancy	1
Operational Efficiency	1
Right-of-Way Availability	4
Safety	22
Schedule	0
Social Concerns	0
Tort Liability Exposure	0

Next Most Common Trade-Off

Access Management	0
Cost	7
Environmental Issue	3
Historic Impact	2
Human Factors/Driver Expectancy	7
Operational Efficiency	4
Right-of-Way Availability	7
Safety	2
Schedule	0
Social Concerns	1
Tort Liability Exposure	4

All Responses

Access Management	0
Cost	14
Environmental Issue	4
Historic Impact	4
Human Factors/Driver Expectancy	8
Operational Efficiency	5
Right-of-Way Availability	11
Safety	24
Schedule	0
Social Concerns	1
Tort Liability Exposure	4

Cross Slope

Most Common Trade-Off

Access Management	0
Cost	10
Environmental Issue	3
Historic Impact	1
Human Factors/Driver Expectancy	3
Operational Efficiency	3
Right-of-Way Availability	3
Safety	14
Schedule	0
Social Concerns	0
Tort Liability Exposure	0

Next Most Common Trade-Off

Access Management	1
Cost	9
Environmental Issue	3
Historic Impact	1
Human Factors/Driver Expectancy	2
Operational Efficiency	4
Right-of-Way Availability	3
Safety	7
Schedule	2
Social Concerns	0
Tort Liability Exposure	3

All Responses

Access Management	1
Cost	19
Environmental Issue	6
Historic Impact	2
Human Factors/Driver Expectancy	5
Operational Efficiency	7
Right-of-Way Availability	6
Safety	21
Schedule	2
Social Concerns	0
Tort Liability Exposure	3

Superelevation

Most Common Trade-Off

Access Management	0
Cost	9
Environmental Issue	2
Historic Impact	1
Human Factors/Driver Expectancy	4
Operational Efficiency	2
Right-of-Way Availability	3
Safety	16
Schedule	0
Social Concerns	0
Tort Liability Exposure	0

Next Most Common Trade-Off

Access Management	1
Cost	7
Environmental Issue	4
Historic Impact	1
Human Factors/Driver Expectancy	5
Operational Efficiency	4
Right-of-Way Availability	4
Safety	6
Schedule	2
Social Concerns	0
Tort Liability Exposure	3

All Responses

Access Management	1
Cost	16
Environmental Issue	6
Historic Impact	2
Human Factors/Driver Expectancy	9
Operational Efficiency	6
Right-of-Way Availability	6
Safety	22
Schedule	2
Social Concerns	0
Tort Liability Exposure	3

Vertical Clearance

Most Common Trade-Off

Access Management	0
Cost	23
Environmental Issue	1
Historic Impact	1
Human Factors/Driver Expectancy	1
Operational Efficiency	0
Right-of-Way Availability	1
Safety	8
Schedule	1
Social Concerns	1
Tort Liability Exposure	0

Next Most Common Trade-Off

Access Management	0
Cost	6
Environmental Issue	3
Historic Impact	2
Human Factors/Driver Expectancy	2
Operational Efficiency	10
Right-of-Way Availability	4
Safety	3
Schedule	1
Social Concerns	2
Tort Liability Exposure	2

All Responses

Access Management	0
Cost	29
Environmental Issue	4
Historic Impact	3
Human Factors/Driver Expectancy	3
Operational Efficiency	10
Right-of-Way Availability	5
Safety	11
Schedule	2
Social Concerns	3
Tort Liability Exposure	2

Horizontal Clearance

Most Common Trade-Off

Access Management	0
Cost	13
Environmental Issue	3
Historic Impact	0
Human Factors/Driver Expectancy	1
Operational Efficiency	0
Right-of-Way Availability	6
Safety	10
Schedule	0
Social Concerns	2
Tort Liability Exposure	0

Next Most Common Trade-Off

Access Management	0
Cost	10
Environmental Issue	3
Historic Impact	1
Human Factors/Driver Expectancy	2
Operational Efficiency	2
Right-of-Way Availability	7
Safety	7
Schedule	0
Social Concerns	0
Tort Liability Exposure	2

All Responses

Access Management	0
Cost	23
Environmental Issue	6
Historic Impact	1
Human Factors/Driver Expectancy	3
Operational Efficiency	2
Right-of-Way Availability	13
Safety	17
Schedule	0
Social Concerns	2
Tort Liability Exposure	2

33. Please list the most common mitigation measures utilized for design exceptions of the corresponding criteria. Does the listed mitigation measure make it more likely, equally likely, or less likely that a design exception would be accepted?

Design Speed

Most Common Mitigation Measure

- Active Traffic Mgmt
- Advanced Warning Signs, Reduced Speed Limit Signs
- Advisory posting for reduced speed
- An evaluation of actual running speeds. However, we typically don't grant design exceptions for this.
- Design exceptions not allowed for design speed
- Haven't done
- Increased Stopping Sight Distance
- Lower posted speed
- N/A
- N/A. Design speed is never excepted.
- NA
- none acceptable
- Other design elements fashioned to support and be consistent with the selected design speed.
- Post curve warning sign
- Properly signing
- Rarely used, but signing could be used
- Reduce posted speed limit
- Reduce posted speed limit
- Reduce Speed Limit
- Reduce travelway width/use curb & gutter section
- reduced design speed
- Reduced posted speed
- Reduction of posted speed
- Right-of-way
- Roadside safety improvements
- Safety
- Signage
- Signage
- Signage
- Signage
- Signing
- Signing, reduced posted speed, VMS messaging and advanced warnings
- Use of urban typical section, medians, landscaping, narrower lanes

Mitigation Measure Impact on Acceptance of Design Exception

15 More Likely

10 Equally Likely

3 Less Likely

Lane Width

Most Common Mitigation Measure

- Adequate shoulder width to pull a vehicle off, milled shoulder rumble strips
- Adjusting speed limit, signing
- An assessment of traffic volume and characteristics -- low volumes and low percentage of trucks may enhance the possibility of a design exception.
- Better wearing surface, better delineation.
- Delineation
- enhanced pavement markings, RPM's
- Improved Alignment
- lack of accident history; other traffic calming measures in appropriate situations
- Lighting
- none
- None
- Optimize shoulder width and condition
- Pavement marking improvements, raised pavement markings
- Rarely used, pavement markings
- Reduce Speed
- Reduce speed limit
- Reduce speed limit
- Reduce speed limit
- reduced lane width
- Reduction of design speed and/or posted speed
- Right-of-way
- Safety
- shoulders/horizontal clearance, wider thru lane than turn lane, low truck volume
- Signage; audible/vibratory pavement marking
- Signage/lane restriction
- Signing
- Signing
- Signing, wide load restrictions at specified times, reduced posted speeds
- Speed reduction and advisory signing
- Striping, illumination, reduce speed
- Striping/pavement markers
- Traffic volumes
- Typically so other criteria can be met -- may have some visible delineation

Mitigation Measure Impact on Acceptance of Design Exception

13 More Likely

18 Equally Likely

0 Less Likely

Shoulder Width

Most Common Mitigation Measure

- Adjusting speed limit, striping
- Driver expectancy
- Flatten surface tapers and in-slopes
- General improvement

- Guardrail
- Guardrail
- guardrail, horizontal clearance
- have used some signing and markings to indicate reduced shoulder
- In low-speed urban environments, other design elements fashioned to support lower-speed operation.
- Increased Clear Recovery
- lack of accident history; low demand for use by bikes or peds
- Lighting
- Milled shoulder rumble strips, narrow lanes slightly to get adequate width for stalled car, paved shoulder
- none
- None needed
- Object markers, signing
- paved shoulders, rumble strips
- Provide wider shoulder in some areas
- Pull off areas
- reduced shoulder width
- Reduction of design speed and/or posted speed
- Right-of-way
- Roadside safety improvements/pavement marking improvements
- Rumble strips
- Rumble strips, occasional pullouts and guardrails
- Signage
- Signing
- Signing
- Signing, reduce speed
- Stabilization of shoulder
- Stable shoulder, better delineation.
- Transverse Pavement Marking in Paved Shoulder; audible/vibratory pavement marking
- visible delineation or rumble strips

Mitigation Measure Impact on Acceptance of Design Exception

18 More Likely

14 Equally Likely

1 Less Likely

Bridge Width

Most Common Mitigation Measure

- Advanced signing of narrow bridge
- Advanced signing of narrow bridge pavement marking improvements
- Advanced Warning Signs
- An assessment of traffic volumes and characteristics.
- Delineators
- delineators, reflectors
- Guardrail on bridge ends
- Increased Sight Distance
- Lighting/signage
- Long bridge
- Low traffic volume and speed
- N/A
- Narrow bridge signs, upgraded approaches.
- narrower crash tested railing
- non
- none
- none
- None

- Not available.
- Object markers
- Rarely applicable--almost always on 3R situations
- Reduce shoulder width
- reduced bridge width
- Reduction of design speed and/or posted speed
- remaining consistent with adjacent highway section
- Right-of-way
- Safety
- Signage; delineator on concrete railings/parapets; upgraded railings
- Signing
- Signing
- Signing
- Signing
- Signing
- Signing, wide load and heavy truck restrictions

Mitigation Measure Impact on Acceptance of Design Exception

11 More Likely

15 Equally Likely

2 Less Likely

Structural Capacity

Most Common Mitigation Measure

- Advanced warning for weight limit enforcement
- Advanced Warning Signs
- Haven't done
- n/a
- N/A
- N/A
- N/A
- N/A. Structural capacity is never excepted.
- None
- None.
- not allowed
- Not applicable--only in 3R situations.
- Not available.
- Not considered
- Not used
- Post bridge
- Post weight limits
- posted load limit
- Posted weight limit
- Posting limits
- Rarely seen but would probably be signing limiting load weight
- Reduced Weight Limits
- Right-of-way
- Safety
- Signing
- Signing
- signing for load limits
- Signing, wide load and heavy truck restrictions

Mitigation Measure Impact on Acceptance of Design Exception

4 More Likely

10 Equally Likely

4 Less Likely

Horizontal Alignment

Most Common Mitigation Measure

- Advance sign warnings, chevron sign in curves, adjust lane within travelway
- Advanced warning per MUTCD
- Advanced Warning Signs
- advanced warning with signing or pavement markings
- Advisory Signing
- Advisory speed signing
- Advisory speed signing
- Chevrons, advisory speed signs
- Delineators, reflectors, signing, chevrons
- Driver expectancy
- Enhanced signing and delineation
- Flattening side slopes through the curve, guardrail installation.
- improve sight distance, signing, speed reduction
- Increase Signage
- Post curve warning sign
- Reduce posted/regulated speeds
- Reduce speed limit
- Reduce speed limit
- reduced speed advisory signing
- reduced speed warning signs
- Reduction of design speed and/or posted speed
- Reflectors on barrier
- Right-of-way
- Signage
- Signage/lower posted speed
- signing
- Signing
- Signing
- Signing, milled shoulder rumble strips, partial width paved shoulders
- Signing, VMS messaging and advance warnings
- signing; widening on curves (not common, but used)
- Speed reduction and advisory signing
- Speed rider
- tighter radius
- Widen shoulders

Mitigation Measure Impact on Acceptance of Design Exception

20 More Likely

13 Equally Likely

1 Less Likely

Vertical Alignment

Most Common Mitigation Measure

- adequate comfort for sag VC, hidden drive/limited sight distance advisory signing
- Advanced warning signs and improve visibility
- Advanced Warning Signs, Street Lighting

- Driver expectancy
- illumination, signing, speed reduction
- Improve lighting
- lighting
- Lighting
- Lighting sag vertical curve
- Lighting/lower posted speed
- Marking no-passing zones
- N/A
- None
- None.
- Reduce speed limit
- Reduce speed limit
- Reduce speed limit
- reduced speed warning signs, lighting
- Reduction of design speed and/or posted speed
- Right-of-way
- sharper vertical curve
- Signage
- Signage for crest curves and lighting for sag curves
- signing
- Signing
- Signing
- Signing, lighting in some cases
- Signing, VMS messaging and advance warnings
- Speed reduction
- Street lighting of substandard sag vertical curves.
- typically would relate to grade or SSD
- Warning signs, advisory speed signs

Mitigation Measure Impact on Acceptance of Design Exception

15 More Likely

14 Equally Likely

2 Less Likely

Grade

Most Common Mitigation Measure

- Advisory signing
- Advisory signing, paved shoulders, shoulder rumble strips
- Improve ability to recover if driver leaves the lane/crash cushions
- Improve Sight Distance
- Installation of truck climbing lanes where warranted.
- longer accel or decel lanes, passing lanes, signing
- None
- Passing lanes
- Provide advance warning sign
- Provide flatter/longer landings
- Reduction of design speed and/or posted speed
- Right-of-way
- Safety
- Signage
- Signage
- Signage (for steepness & passing zone locations)
- signing
- Signing

- Signing
- Signing
- Signing
- Signing
- Signing
- Signing
- signing or climbing lane
- Signing, escape ramps, passing opportunities
- Signing, VMS messaging, advance warnings, climbing lanes, passing lanes and truck escape ramps
- Speed reduction
- steep grade advisory signing
- steeper grade
- Truck climbing lane
- warning signs
- Warning signs, advisory speed signs

Mitigation Measure Impact on Acceptance of Design Exception

18 More Likely

15 Equally Likely

1 Less Likely

Stopping Sight Distance

Most Common Mitigation Measure

- Adjust horizontal/vertical curve alignments
- Entrance/Intersecting Road relocation
- Evaluation of features associated with the site.
- Improve signage
- Improve signing, advanced warning and reduce posted speeds
- Lighting sag vertical curve
- lighting, lower posted speed; signage
- Lower posted speed/signage
- Marking no-passing zones
- none
- none
- not considered
- Reduce Speed
- Reduce speed limit
- Reduce speed limit
- Reduce speed limit
- reduced speed advisory signing
- Reduction of design speed and/or posted speed
- Right-of-way
- Safety
- Signage advance warning
- signing
- Signing
- Signing
- Signing and reduced posted speeds
- Signing and/or lighting
- Signing, advisory signing
- signing, illumination
- SSD is rarely excepted but could be mitigated with speed reductions or signing
- Use a low barrier when median barrier is a sight obstruction.
- Widen Shoulder

Mitigation Measure Impact on Acceptance of Design Exception

16 More Likely

12 Equally Likely

1 Less Likely

Cross Slope

Most Common Mitigation Measure

- Additional drainage features
- Closely spaced drainage inlets or other drainage facilities
- Consider lower posted speed (urban areas).
- Drainage improvements
- high-friction asphalt; signing
- improve drainage
- Improve signage
- Improve surface friction
- improved drainage
- improved drainage where flatter than criteria, low speed urban where higher than design criteria
- N/A
- none
- none
- none
- none
- None
- None
- None
- None.
- Place crown points at edge lines
- reduced % of cross slope
- Reduction of design speed and/or posted speed, increased drainage features
- Right-of-way
- Safety
- signage (slippery when wet); open graded friction course
- Signing
- Signing
- Unknown
- Use of OGFC, PEM, grooving
- Wearing surface friction

Mitigation Measure Impact on Acceptance of Design Exception

11 More Likely

11 Equally Likely

2 Less Likely

Superelevation

Most Common Mitigation Measure

- Advanced Warning Signs
- advanced warning with signing or pavement markings
- Corrected or advanced signing per MUTCD
- Flattening the side slopes through the curve, guardrail installation.
- high-friction asphalt, signing
- Improve drainage
- Improve surface friction
- Lower posted speed

- lower posted speed, improve skid resistance
- None
- None
- None.
- Pavement markings, rumble strips
- Post curve warning sign
- Reduce Speed
- Reduce speed limit
- Reduce speed limit
- reduced speed advisory signing
- reduced speed warning signs
- reduced superelevation
- Reduction of design speed and/or posted speed
- Reflectors on barrier
- Right-of-way
- Roadside safety improvements
- Safety
- Signage
- Signage
- signing
- Signing
- Signing and reduced posted speeds
- Speed reduction and advisory signing
- Wearing surface friction, advisory signs

Mitigation Measure Impact on Acceptance of Design Exception

13 More Likely

14 Equally Likely

3 Less Likely

Vertical Clearance

Most Common Mitigation Measure

- Advance signing, truck restriction
- Advance warning for motorists
- Advance warning signs
- Advanced warning signs
- Advanced Warning Signs
- Advisory signing
- Another route with adequate clearance
- Improve signage
- Not used. Signing
- Provide alternative truck routes
- reduced vertical clearance
- Right-of-way
- Safety
- Sign and redirect oversize vehicles to another route
- sign and redirect oversize vehicles to another route
- Sign and redirect oversize vehicles to another route
- Sign and redirect oversize vehicles to another route
- Signage
- Signage
- Signage
- Signage for vertical clear
- signing
- Signing

- Signing
- Signing
- Signing
- Signing
- Signing
- Signing, load height restrictions, and advance warnings
- signing, public outreach, detours
- Signing.
- Truck restrictions
- warning signs

Mitigation Measure Impact on Acceptance of Design Exception

18 More Likely

13 Equally Likely

2 Less Likely

Horizontal Clearance

Most Common Mitigation Measure

- barrier
- Barrier
- Barrier to shield object
- Delineate objects
- Delineation
- delineation of roadside obstacles
- Delineation, shielding
- delineation, shielding, reduce pole conflicts with joint use requirements.
- Guardrail
- Guardrail
- Guardrail
- Guardrail, cable rails and crash barriers
- Improve signage
- installation of barrier
- Lane width, parking width
- Lighting improvements
- Lower posted speed/guardrail
- narrower crash tested bridge barrier, remove brush blocks, max lane width
- none
- none
- None
- Placement of object(s) to minimize operational interference.
- reduced horizontal clearance
- Reduction of design speed and/or posted speed
- Right-of-way
- Safety
- Shielding
- Signing
- Signing
- Signing/lighting.
- Warning signage

Mitigation Measure Impact on Acceptance of Design Exception

14 More Likely

13 Equally Likely

1 Less Likely

Future

34. Are there any plans to reevaluate how your agency evaluates trade-offs in the design selection process in the next 6 to 12 months?

10 Yes

29 No

Please explain what potential changes may be considered or why no change is planned.

- Adequate process in place.
- all aspects of design are already considered for each project with current procedure
- CDOT is developing policies and recommendations for the Practical Design concept for implementation in the near future.
- continue to update policy and improve safety analysis tools
- Criteria recently updated.
- Currently, no changes are planned as there have not been any problems with current policy.
- Further development of AMFs for SSD would be helpful in evaluating tradeoff, currently utilizing HSM for safety tradeoff, its use will be expanded.
- In our agency there should be on how to evaluate trade-offs in the design select process.
- No discussion of changes at this time.
- No overarching change planned. The current method of comparing effects and costs with benefits is intended to provide a balanced outcome. We are looking at livable/sustainable community aspects and how to best incorporate into current standards and practices. Resources constraints also affect our ability to develop and implement new procedures.
- No plans because the issue has not become "hot" within the Department
- Our Project Development Process is being re-evaluated by Department staff. The evaluation of the design is part of this process.
- Planning to implement monitoring of performance in locations where design exceptions have been approved.
- Schedule periodic review
- The guidance is relatively new for us and was difficult to get approved, so we will be looking at ways to improve it now that it is in place.
- There is an overall policy initiative towards a flexible design policy and practice, which includes the continued emphasis of context sensitive design as our overarching goal as well as emulation of Missouri DOT's Practical Design in some form. As part of this initiative, we are re-examining our standard design criteria, starting with the 13 critical elements, with special emphasis on elements where Mn/DOT policy exceeds AASHTO *Green Book* policy.
- This does not seem to be a problem for our agency at this time.
- Through practical design efforts over the past 5 years, MoDOT manages tradeoffs as a routine part of doing business.
- Using the *Highway Safety Manual* to evaluate on a project-specific basis various tradeoffs in roadway cross-section options to stay within existing right-of-way.
- We are always willing to consider changes to our process. However, we do not have a formal review scenario for this.
- We have planning training dealing cost benefit analysis during the design process which should create additional documentation to be used as a resource.
- We're satisfied with our current process

35. Are there any plans to reevaluate how your agency evaluates design exceptions in the next 6 to 12 months?

5 Yes

34 No

Please explain what potential changes may be considered or why no change is planned.

- Adequate process in place.
- continue to update policy and improve safety analysis tools
- Currently, no changes are planned as there have not been any problems with current policy.
- Currently, no changes are planned as there have not been any problems with current policy.
- Heightened awareness to proper documentation was begun years ago and is improving. Training modules have been developed so that we can have few re-submittals in the future.
- MoDOT recently reevaluated its design exception policy and arrived at a solution that's mutually acceptable to the Central Office, the Districts and the FHWA.
- No discussion of changes at this time.
- Our procedure is constantly evolving and may be revised as the need occurs

- Planning to place more emphasis on risk and cost related to design exceptions.
- Recently updated.
- Schedule periodic review
- The current tool is effective if properly used.
- The design exception process will be evaluated as part of an on-going annual review of our State design manuals.
- The guidance is relatively new for us and was difficult to get approved, so we will be looking at ways to improve it now that it is in place. Some of the criteria that we could not get agreement with FHWA hasn't been approved yet. Also, we will be writing an new 3R agreement soon.
- This does not seem to be a problem for our agency at this time.
- Very few Design Exceptions processed by our Division.
- We have an successful design exception process
- We have planning training dealing with mitigation strategies for design exceptions but we do not have any plans to change the evaluation process.
- We have recently received a seminar about how to prepare design exceptions and the documentation for liability issues
- We recently went through a continuous-improvement evaluation of our design exception process, which is currently in the process of implementation.
- We're satisfied with our current process

Summary

36. We are interested in any further comments that you may have with regards to how your agency deals with risk in the design selection process when evaluating trade-off considerations in highway geometric design.

- As mentioned previously, PennDOT's Smart Transportation approach is focused on applying criteria that is aligned with the surrounding project area.
- For new alignments, we generally want to meet all standards. For projects on existing alignments that have substandard conditions, we will evaluate accident data. Depending on what the data reveals, the substandard elements will either be considered acceptable, or will be mitigated fully or partially.
- I would like to comment on a couple of areas: **Design Exceptions:** Although SHA does follow a process for design exceptions, we do not frequently apply for them. Most cases that we have applied for recently are existing conditions which we are improving but not correcting to 100% AASHTO compliant. However, that decision is based off of the existing safety issues that the existing condition may or may not have. If there are no existing safety issues with the deficient design, we are less likely to make it 100% compliant if funding is an issue or if there are significant impacts. If the existing condition does present a safety issue, SHAwill make every effort to address deficient design with less emphasis on costs or impacts. Basically, safety will always be the main deciding factor on whether or not a design exception will be allowed or considered. **Risk Assessment:** Once again safety is typically the deciding factor when it comes to assessing what risks SHA will take when modifying or deciding on design features. There is no formula or tool used to help bring SHA to a final decision, rather engineering judgment along with historical data and trade-offs are all considered when making a final decision.
- Interested in how other states determine when design exceptions are necessary. Our FHWA office considers anything that the AASHTO *Greenbook* says "should be considered" to be a requirement. Also, how others handle criteria that is not from the AASHTO *Greenbook*. For example, LRFD or Design Standards Interstate System. We are required to do design exceptions for anything in these documents, not just the 13 controlling criteria.
- It would be nice to have some low cost/high impact improvement guidelines in order to achieve a good design without sacrificing safety.
- Much of the information regarding Design Exceptions was left blank as our agency does so few throughout the year that there are no mitigation measures that would be considered common or more likely to be used than another.
- none
- None
- None.
- Our evaluation of risk is primarily a decision by knowledgeable design professionals considering documented facts and input from stakeholders.
- Risk analysis, per se, is not undertaken. It's mainly a matter of geometric and operational safety vs cost to upgrade.
- Too worn out after the last 34 questions to offer any additional feedback.
- VDOT has used risk matrices on a number of Public Private roadway projects where the scope of work is still somewhat vague due to the fact that 30% plans are used to negotiate contracts. Roadway designers utilize the information in the FHWA publication "Mitigation Strategies for Design Exceptions" and numerous NCHRP reports to make sound engineering judgment related to design trade-offs. Any new guidance related to risk management and/or design criteria evaluation from AASHTO will be greatly appreciated.

- We are shifting to a Matrix type of organization at this time and part of the process is to look at more risk analysis on projects. Currently we have consultants perform risk analysis on projects over $100 million and are looking at doing a reduced risk analysis on projects above $20 million. The problems we are facing at the moment are a very small staff in our cost estimating group and because of the economy the possibility of expanding that group isn't looking promising at the moment.
- We are using a "Complete Streets" approach and consider the needs of all users (motorist, bicyclist, pedestrian) as we look at trade-offs and risk. We consider all projects on a case by case basis considering the context, and balance lane widths, shoulder widths and sidewalks for accommodations of all users.
- We would like to increase our evaluation of risk during the design selection process.
- While many of the pieces of this survey are beneficial, the term trade-off is a difficult one to define in my mind. Highway projects are a balance of so many factors, while we may use the flexibility within our standards to navigate the host of issues, I would not necessarily consider that a "trade-off."

Abbreviations used without definition in TRB Publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETY-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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