CORRIDOR AND SYSTEMWIDE APPLICATION OF PERFORMANCE BASED PRACTICAL DESIGN

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16. Abstract

This report reviewed the state of practice for Performance Based Practical Design (PBPD) in the United States, with a review of available literature and State DOT guidelines. This was supplemented with a survey distributed to State DOTs and interviews with MDOT business units. Ultimately, a series of recommendations was suggested for how MDOT could implement PBPD within their business processes, and other agencies may look to these to support their own efforts at PBPD. Common PBPD threads include (1) safety should not be compromised for any reason; (2) project needs, goals, purpose, and objectives need to be clearly stated for the successful implementation of PBPD; and, (3) Focus should be on the transportation system as a whole, rather than on individual projects.

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To better utilize limited funding when addressing system performance, mobility, and safety needs, many agencies have been moving towards implementing practical design into their workflows. The premise of practical design is to narrowly scope a project to meet a specified purpose and need, and considering past performance of the facility to determine where design may be optimized without reducing safety performance. This data-driven approach has become known as “Performance-Based Practical Design”, or PBPD. Common threads of PBPD from the other states reviewed include:

- Safety should not be compromised for any reason.
- Project needs, goals, purpose, and objectives need to be clearly stated for the successful implementation of PBPD.
- Focus should be on the transportation system as a whole, rather than on individual projects.

Many states have implemented some form of PBPD into their planning and design processes, and the American Association of State Highway and Transportation Officials (AASHTO) has increasingly added these flexible design considerations into their design reference, “A Policy on Geometric Design of Highways and Streets” (2018). This research examines the current practices of PBPD in other states, surveyed other state DOT practitioners for their views on PBPD, spoke with different business units within MDOT, and finally suggests opportunities for MDOT to expand the use of PBPD within Michigan.

1. Introduction and Overview

The Federal Highway Administration (FHWA) and state departments of transportation (DOTs) across the country face increasing challenges in addressing their system performance, mobility, and safety needs in consideration of budget and resource limitations (*1*). To manage this issue, states have been increasingly moving towards implementing practical design into their projects. Practical design is built upon the concept of scoping projects to better fit within a project's core purpose and need, exploring opportunities as supported by safety analysis to potentially remove various elements to reduce costs. As cost savings in the near-term may influence longer-term corridor- or system-wide objectives, this has led to the creation of the evaluation method of performance-based practical design (PBPD). PBPD is defined as "a decision-making approach that helps agencies better manage transportation investments and serve system-level needs and performance priorities with limited resources" (*1*). The flexibility provided by practical design allows states to develop efficient design solutions and construct "...good projects, not great projects, to achieve a great system" and help maximize fix options within available budgets (*2*).

The 7th edition of A Policy on Geometric Design of Highways and Streets (AASHTO Green Book) proposes a geometric design approach that is more flexible and performance-based to address all transportation modes and cater to funding challenges (*3*). This performance-based approach aims to establish the purpose and need for the project without introducing unnecessary costs, which helps in right-sizing the scope of the project and hence saves the resources for other needs throughout the roadway system (*3*). Furthermore, it provides maximum results with limited funding, tailored solutions for the project's purpose and need, and addresses critical issues in priority, making it a suitable consideration for any transportation agency (*4*). In addition, this approach is consistent with the Highway Safety Manual's (HSM) goal of moving away from nominal safety (adherence to geometric criteria) to substantive safety (safety performance of designs), which allows enhancements to safety or a "design up" approach. In this approach, the starting point of a design is the existing conditions, and the applied treatments are chosen based on their safety, operational, and cost benefits to meet the needs of the site and the rest of the roadway network while still adhering to a state's engineering design standards (*1*).

PBPD has been built upon the concepts of context sensitive solutions (CSS), flexibility in design, value engineering, and asset management. Since the emergence of CSS in the 1990s, agencies have been trying to develop transportation solutions through a collaborative and interdisciplinary approach that includes various stakeholders' views to create clear project goals. With the growth in CSS, a trend towards flexible design emerged to provide transportation solutions without compromising safety. This is similar to value engineering, which was introduced to provide transportation solutions that ensure safety, reliability, and cost-efficiency (*5*), as well as practical design, which critically reviews the project to reduce cost and set the roadway geometry to serve needs rather than standards (*6*).

With advances in data collection technology, availability and reliability of traffic and safety data (such as volumes or crash history) has increased. Furthermore, the use of data has been stressed through Moving Ahead for Progress in the 21st Century Act (MAP-21) and other federal initiatives. As a result, the FHWA encourages state transportation agencies to use a data-driven approach to develop projects that forms the basis of PBPD. It should be noted that PBPD is not a replacement for CSS, value engineering, or any other related approaches, but it is a complement that supports informed decision-making.

The preceding discussion demonstrates a clear need to develop methods and tools that can be used at the early planning stage in order to aid transportation agencies in key design decisions. For these methods and tools to be broadly useful, it is important for them to be applicable across various contexts. To that end, the purpose of this project is to assist the Michigan Department of Transportation (MDOT) in the development of decision support tools for use in applying PBPD corridor-wide, allowing for project prioritization and detailed modal analyses. The objectives of this project are as follows:

- Develop a flexible and data-driven design approach that leads to more financially sustainable results-oriented projects and corridor consistency.
- Recommend PBPD application values based on roadway type for the ten (10) controlling roadway design elements as specified in the AASHTO Green Book (3):
    - Design speed
    - Lane width
    - Shoulder width
    - Horizontal curve radius
    - Super elevation rate
    - Stopping sight distance (SSD)
    - Maximum grade
    - Cross slope
    - Vertical clearance

    - Design loading structural capacity
- Apply new data and knowledge at the system or corridor-wide level to define other PBPD guidance oriented toward solving problems more reliably and efficiently.
- Suggest changes to the Road Design Manual and any applicable MDOT standards (where pertinent), based upon the results of this research project.
- Develop goals for performance characteristics with required data collection requirements, and use of tools (both existing and newly developed) to measure against those goals based on data showing actual performance of roadway features. This allows for comparative analysis and a greater understanding of the impacts of improvements or physical features to determine the desired outcomes.

In consideration of these objectives, the following sections of this report provide extensive details of agency practices and key elements related to PBPD:

- Chapter 2 provides a review of the evolution and chronology of PBPD with emphases on key milestones, underlying principles, and example case studies that demonstrate applications of this approach.
- Chapter 3 presents a formal review of existing state DOT guidelines related to PBPD; and finally,
- Chapter 4 presents results from a state agency survey focused on identifying existing policies, practices, and guidance on PBPD, as well as associated performance measures and methods for evaluating the efficacy of this approach.
- Chapter 5 summarizes discussions with several MDOT business units identified by the Research Advisory Panel.
- Chapter 6 provides links to and a summary of various data sources, tools, and procedures used to make data-driven decisions when comparing performance.
- Chapter 7 provides a review of known Design Exceptions and Design Variances requested from January 2018 to March 2022.
- Chapter 8 contains the recommendations identified during the course of this research for implementing Performance Based Practical Design in Michigan. This includes recommendations for additional research and considerations.

2. REVIEW OF NATIONAL STATE-OF-PRACTICE FOR PERFORMANCE-BASED PRACTICAL DESIGN

The research team conducted a comprehensive review of research reports, peer-reviewed publications, and other resources that detail national, state, and local practices of PBPD. This allowed for the identification of different forms of PBPD, associated principles and characteristics, and the role of PBPD in transportation/network planning and project development. Additionally, this review helps to frame how MDOT and other agencies may best achieve PBPD, including the relationship between pertinent treatments and design controls, as well as performance measurement programs that are foundational to PBPD. Lastly, this review helps to identify potential gaps and opportunity areas to strengthen MDOT's project development processes in consideration of project-, corridor-, and system-level needs.

2.1. History and Development of PBPD

Many states and local agencies have recently adopted PBPD policies or are making strategies to apply PBPD in their transportation projects. Though the foundation of PBPD was laid in Missouri in 2005, through the Missouri Department of Transportation (MoDOT), the concept of PBPD was initially known as Practical Design (*7*). The following points explain the chronological development of PBPD as a transportation policy in the U.S. (*6*):

- The Missouri Department of Transportation (MoDOT) first pitched the concept of PBPD in 2005 to stretch the limited funding available for projects, called Practical Design. The aim was to achieve a great system by building good projects and not great projects.
- The Idaho Transportation Department (ITD) followed suit and initiated its variant of Practical Design in 2007 based on MoDOT's positive feedback. The goal of this guidebook was to assist in building cost-effective projects so that a safe and efficient transportation system could be achieved.
- The Kentucky Transportation Cabinet in 2008 adopted Practical Solution as a policy with the aim to find a way to do more with less resources by identifying project needs and framing the project scope to suit the need.
- The Kansas Department of Transportation (KDOT) issued a document called Practical Improvements in 2009, which guided the processes to be followed when implementing practical improvement, especially in the development of alternative scopes.

- The Oregon Department of Transportation (ODOT) adopted its Practical Design Policy in 2010. The goal of this was to develop/encourage practices that could incorporate maximum flexibility in design standards such that safety and mobility could be achieved while reducing the cost.
- The Utah Department of Transportation (UDOT) issued its Practical Design Guide in 2011. The Practical Design guide was not developed to provide different design criteria, but to offer general guidelines for implementing Practical Design.

The National Cooperative Highway Research Program (NCHRP) produced a framework in 2014 on integrating performance-based analysis into geometric design decisions and the effects of different geometric elements on project performance measures (*8*).

2.2. Principles of PBPD

PBPD is a collaborative and interdisciplinary approach, which helps in greater stakeholder participation and the development of transportation solution that suits the context of the area. The AASHTO green book defines PBPD as an approach that makes key decisions with consideration for their expected effects on aspects of future project performance relevant to the project purpose and need. Within the AASHTO Green Book, PBPD is defined as the current state of practice for delivering highway improvements (*3*). Hillis (2016) describes practical design as a multidisciplinary approach to deliver transportation projects that focuses on the well-being of the whole system, enhances roadway safety, improves cost-effectiveness, and is also sensitive to the context and stakeholders' needs (*9*). FHWA defines PBPD as a "decision-making approach that helps agencies better manage transportation investments and serve system-level needs and performance priorities with limited resources" (*10*). Most practitioners believe that PBPD should be guided by a set of principles rather than giving it a rigid definition (*7*). Hillis (2016) suggested five PBPD core principles to help each state create guidance that matches its own unique need (*9*).

The PBPD core principles are:

- Maximizing transportation system solutions within the available funding to achieve the system's best possible outcomes.
- Achieving the best possible balance between a project's cost, quality, and timeliness of delivery while maintaining safety.
- Emphasize adding value rather than only reducing cost.

- Involving local community and stakeholders to identify the project's purpose and need throughout the program development and delivery process.
- The determination of the purpose and need of a project by:
  - Focusing on doing as much as possible across the entire network to yield the greatest benefit.
  - Reviewing the corridor as a whole, not just the project location, along with parallel and perpendicular road networks.
  - Accounting for all aspects of the program delivery process from initial planning through construction and into operations and maintenance.
  - Having multiple tiers of performance-based outcomes as well as non-quantifiable outcomes such as community benefit and approval/support.

Designing a project to its purpose and need rather than to standards helps to prevent overdesign and ensures that projects are correctly sized (7).

2.3. Purpose, Need, and Benefits of PBPD

Infrastructure projects have continued aging, increasing consideration for environmental concerns and right of way associated with rebuilding this infrastructure (*11*). Dollar and staff resources have continued to be strained, causing budgets and staff to be stretched for efficient and effective use. This has created a need for agencies to develop data driven solutions to confront transportation challenges and their associated constraints by clearly understanding the project purpose and need. PBPD allows agencies to develop project scopes that support cost reduction, which could then be applied to other roadway features where a more significant impact can be realized while not compromising performance, safety, or mobility.

The benefits of applying PBPD can be summarized as according to (*12*):

- Help focus on performance improvements that benefit both the system and project needs.
- Help strengthen corridor-level planning or system performance needs and objectives during individual projects' planning, scoping, and development.
- Create a need for greater return on infrastructure investment by assessing each element of a project's scope relative to its value, need, and urgency.
- Enable agencies to make decisions based on historical system performance and anticipated maintenance requirements.

2.4. PBPD in Transportation

The importance of integrating PBPD into the transportation infrastructure design cannot be overstated as transportation agencies have limited resources to invest in projects and also have to deal with constraints imposed by the environment (*8*). Ray et al. (2014) identified three guiding principles needed to create usable, practical, and long-lasting highways and streets (*8*):

- Intended outcomes: This will involve documenting the importance and need for each project and then completing a performance-based analysis of the geometric design to meet the intended outcomes; sometimes geometric design elements are affected by the intended outcomes or vice versa.
- Connection to project development process: This requires the involvement of the facilities' users in the project development phase, particularly the environmental evaluation process (NEPA) and documentation.
- Performance measures of design decisions: This primarily affects the performance effects of geometric design. This provides a summary and a priority list of measures that are sensitive to geometric design decisions.

Figure 1, shown below, identifies the six basic stages in performance-based analysis to inform geometric design.

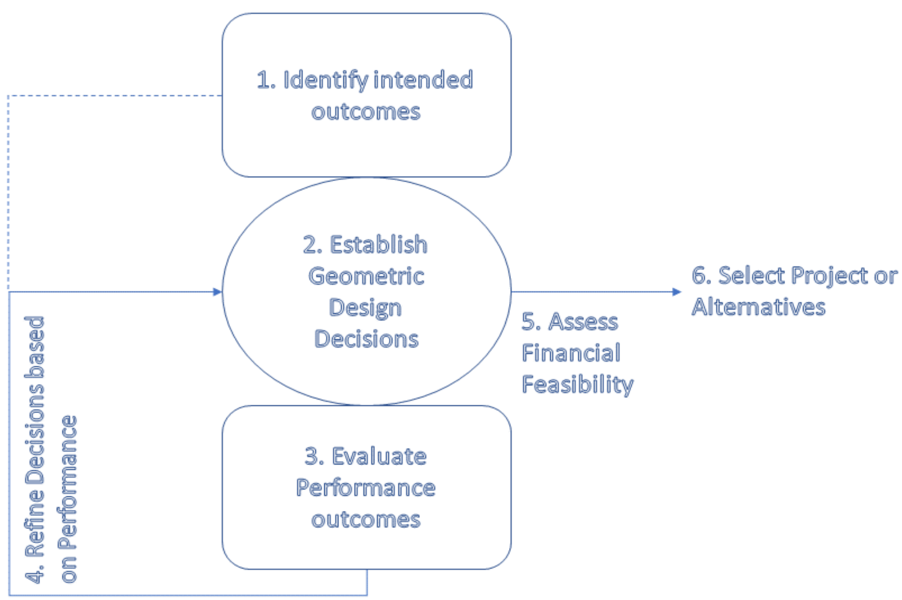

Figure 1 - Fundamental model for performance base analysis of geometric design of highways and streets (8)

The explanation of these six stages is as follows:

1. Identifying the project's intended outcome: Some of the outcomes could be safety, a state of good repair, livable communities, and/or economic competitiveness. These outcomes help establish measures against how each project or design is analyzed. Congestion reduction, environmental sustainability, freight movement and system reliability are also considered.
2. Establishing Geometric Design: This involves the development of preliminary designs and the establishment of design criteria to evaluate each design.
3. Evaluating the performance of the geometric design: The performance outcomes of the different geometric design options are considered and are evaluated based on the criteria established.
4. Iteration of design and outcomes to achieve optimization: This depends on the result obtained from assessing the performance of geometric design options. There could be an iterative procedure to align the geometric design performance with the project's intended outcome. If this cannot be achieved, re-evaluation of the project's outcome may be necessary to review alternate options.
5. Evaluation of benefit-cost: This involves the assessment of the benefit and the design choices to obtain the value of the geometric design solution compared to the intended outcome. If more than one design meets the project outcome and all other factors are considered constant, the design with the greater value of benefit-cost should be chosen.
6. Select or advance project or alternatives: Project alternatives may be submitted for a more detailed evaluation or review.

The definition of a project's intended outcome will enable users to assess the performance results of alternative designs or configurations.

2.4.1. Other Performance-Based Disciplines In Transportation

Other transportation disciplines have also adopted performance-based methods beyond geometric design. One of the first systematic reviews of performance-based considerations in transportation was conducted in Transportation Research Board's (TRB) National Cooperative Highway Research Program (NCHRP) Report 446 ("A Guidebook for Performance-Based Transportation Planning", 2000). Per the research, it found that utilizing performance outcomes are "intended to result in transportation plans, programs, and decisions driven by the needs of the specific area, rather than by the modal restrictions on funding sources or support programs" (*25*). This resulted in an understanding that rigid adherence to standards may be less desirable than a balanced, data-driven approach for the specific project.

NCHRP Report 785 ("Performance-Based Analysis of Geometric Design of Highways and Streets", 2016) was one of the first comprehensive studies of performance-based design and presents an approach for understanding the desired outcomes of a project, selecting performance measures that align with those outcomes, evaluating the impact of alternative geometric design decisions on those performance measures, and arriving at solutions that achieve the overall desired project outcomes (*26*).

NCHRP Report 949 ("Proposed AASHTO Guidelines for Performance-Based Seismic Bridge Design") provides guidelines for performance-based seismic bridge design (PBSD) that are intended to be used by bridge engineers and designers (*27*). The guidelines are based on the principles of performance-based design and are intended to provide a framework for designing bridges that can withstand seismic events. The report includes information on the seismic hazard, ground motion, and site effects that should be considered when designing bridges. It also includes information on the performance objectives that should be used when designing bridges, as well as the performance measures that should be used to evaluate the performance of bridges during seismic events. Finally, the report includes information on the design criteria that should be used when designing bridges for seismic events.

In NCHRP Research Report 954 ("Performance-Based Management of Traffic Signals") the researchers investigated and discuss the importance of performance-based management of traffic signals and how it can be implemented (*28*). It also includes case studies and best practices for traffic signal management. It also covers topics such as data collection and analysis, and system optimization.

One of the most recent documents regarding performance-based design is in NCHRP Report 972 ("Development of Safety Performance-Based Guidelines for the Roadside Design Guide") (*29*). The guidelines are intended to provide a performance-based approach to roadside safety design that will help reduce the number and severity of crashes on our nation's highways. The guidelines are based on the latest research and best practices in roadside safety design and are intended to be used by state and local transportation agencies, as well as private sector engineers and designers. More than 60 years ago research found that approximately one-third of highway fatalities were occurring in run-off-road crashes, and this proportion has largely remained unchanged to the present day. In many parts of the country – including in Michigan – single-vehicle run-off-road (SVROR) crashes are the largest share of an agencies severe or fatal crashes. Quantifying performance aims at using data to drive decisions rather than relying on rigid inputs, ultimately working to minimizing vectors for potential risk or serious injuries or fatalities and maximizing the safety of transportation facilities.

2.5. Procedures to Achieve PBPD

FHWA published a start-up guide in 2017 to help states and transportation agencies develop their PBPD programs. The guide listed some points to be noted at the start of PBPD. They are (*13*):

- The possibility of implementing PBPD in the federal-aid Highway Program regulatory environment by utilizing existing flexibility.
- PBPD does not modify, compromise, or eliminate existing design standards or regulatory requirements.
- PBPD approach seeks a greater return on investments by paying attention to each element of a project's scope relative to its value and need.

FHWA has identified four steps to achieving PBPD, outlined in Table 2.1 below (*13*):

Table 1 - Four steps to achieving PBPD (13)

Step/Phase	Key Element	Details
Learning	Becoming PBPD Advocates	This involves Someone at the state agency must genuinely believe in the PBPD approach. Advocates who support PBPD goals vocally at both the staff and leadership level can help to effect and accelerate cultural changes.
	Learning More about PBPD	This would involve talking to other states about their successes and how they have achieved those successes.
Marketing	Obtaining Executive Buy-in	This involves educating the organization's leaders on the value and importance of PBPD. This is necessary to get support from leadership in facilitating a cultural shift in the organization towards PBPD.
	Gather Stakeholders	This involves assembling all stakeholders in the organization at the outset of PBPD. This will help to foster an atmosphere of partnership. The stakeholders' groups are policy, procurement, planning, design and construction, environmental, operations, and safety. A partnership should also be formed with regulatory agencies.
Rolling out	Determination of the Baseline	This involves the identification of existing processes, tools, resources, and practices that currently guide an agency's planning and project development activities.

Step/Phase	Key Element	Details
	Setting a Goal	This involves building on the existing state of practice. A goal should be identified and an intermediate milestone identified. The goal should compare the value of projects to funding or other key organization measures.
	Establishing a Schedule	This involves working with the PBPD team to develop a realistic timeframe as implementing a new program and shifting an organization's way of thinking could take time. Scoping, planning, and developing PBPD is expected to take 18 to 24 months.
Execution	Familiarity with Data and Analytical Tools	This involves training staff with the knowledge of safety and operational tools, such as the Highway Safety Manual, the Highway Capacity Manual, Safety Analyst, and Traffic Simulation. This creates an understanding of each alternative's safety and operational implications.
	Provision of Technical Support to Staff	Leadership should create opportunities that will provide training and support to staff. This will help staff understand how performance tools and data are used to make informed decisions. It would also help them understand their role better and communicate to others through the lens of PBPD.
	Creating a Sense of Team	This requires effective communication when goals and targets are being set. Also, each milestone reached in achieving PBPD should be recognized.

To achieve PBPD it is also necessary to involve the stakeholders, use proven measures to successfully apply PBPD, establish methods/practices to measure and monitor opportunities and implementations, and overcome any challenges/barriers that come up while applying this concept.

2.5.1. Public Involvement in PBPD

Public involvement in the planning process helps ensure that the project will meet its needs and goals. As such, attempts have been made by some state DOTs to involve the public in some degree with the decision-making process. However, Oregon Department of Transportation explicitly mentions that public support and involvement are essential to successful implementation of PBPD; "working with locals provides opportunities for the community to shape the chosen solution, and consider the needs for pedestrians, bicyclists, transit users, freight and mobility" (*14*). Similar explicit attempts by other state DOTs can improve the status of public involvement to achieve PBPD.

2.5.2. Widely Adopted Measures for PBPD

While each state has different guidelines for PBPD, there are some widely adopted measures and goals between states (*6*), as follows:

- Overall goal is to optimize entire system's safety and operational performance rather than a specific site.
- Project is designed to fit the purpose and need in the most cost-effective approach, not to do more than that or to fit a specific solution.
- Encourage design flexibility to meet system needs but do not eliminate engineering design standards.
- Begin with existing conditions and minimum improvements needed while moving towards a "design up" approach to improve the site.
- Encourage development teams to implement data supported engineering judgement in decision-making versus strict adherence to design standards.

2.5.3. PBPD Measurement

PBPD is often measured by cost savings. Missouri was the first state to implement practical design into their projects in 2004, and it resulted in a cost-savings of $1.2 billion from 2005 to 2009. The next state to do so was Idaho in 2007, which saved them $27.2 million within the first year and over $50 million total since implementation. Kentucky implemented practical design in 2008, saving them $4.7 million on just one intersection improvement project. Utah was the most recent state to do so in 2011, though they had not reported the value of savings at the time (*15*).

2.5.4. Barriers to PBPD Implementation

According to states who have implemented practical design policies, there are not any barriers/challenges to PBPD implementation that cannot be overcome through appropriate training, education, and communication with the stakeholders (*6*). However, there were initial concerns from staff about not strictly following engineering design standards until their training stressed the importance of not compromising safety and enforcing support of utilizing engineering judgment (*6*).

2.6. Review of PBPD Case Studies

The Federal Highway Administration (FHWA) has published a series of case studies on PBPD, which are summarized in the following subsections.

2.6.1. Arizona DOT

Upon reviewing crash data, the Arizona Department of Transportation (ADOT) found that a substantial number of crashes on rural two-lane roads were run-off the road crashes. SR264 is one such two-lane rural highway that was selected as a high priority corridor in Navajo County, Arizona, pictured below in Figure 2.

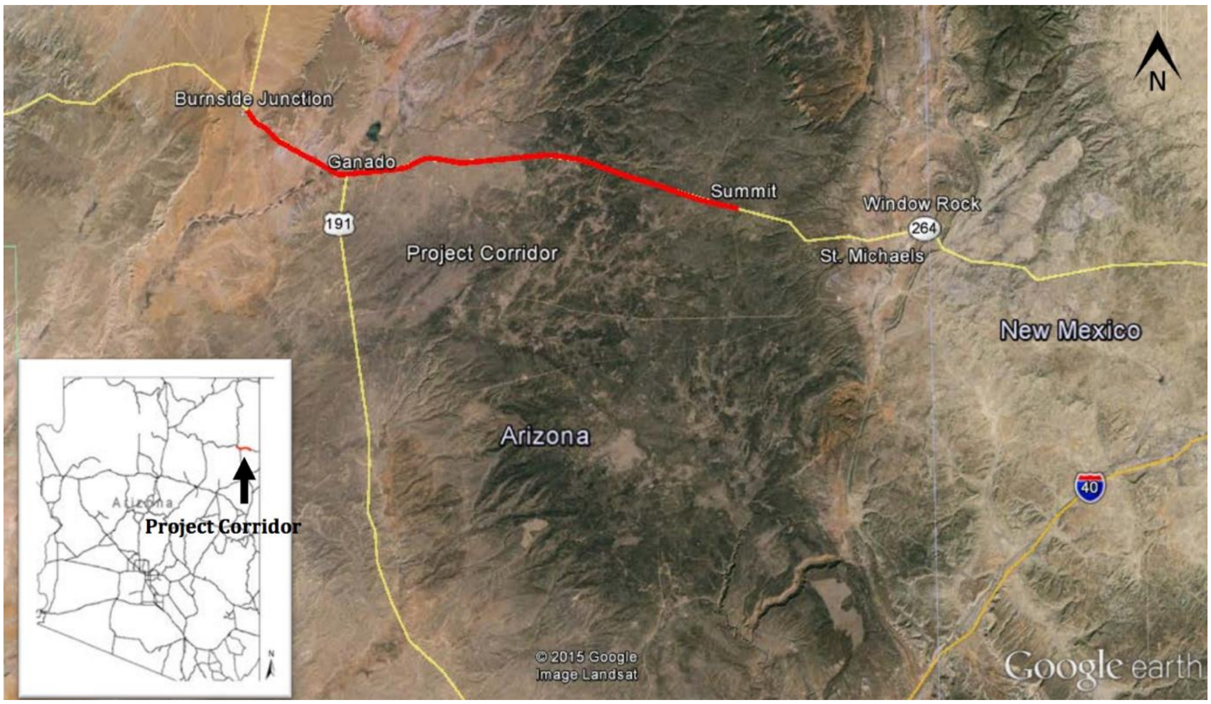

Figure 2 - Section of SR 264 of interest (16)

The following safety improvements for this section of SR 264 were considered:

- Shoulder widening alternative A—5 ft shoulders
    - Includes adding centerline and shoulder rumble strips, flattening side slopes, adding guardrail and delineators, extended drainage structure, and recessed pavement markers.
- Shoulder widening alternative B—8 ft shoulders
    - Includes adding centerline and shoulder rumble strips, flattening side slopes, adding guardrail and delineators, extended drainage structure, and recessed pavement markers.
- Superelevation compliance with AASHTO standards

A safety analysis of this corridor was done using the Highway Safety Manual. It was found that alternative A would provide a 16% reduction in crashes and alternative B would provide a 21%

reduction in crashes, with alternative A having a cost-benefit ratio of 2.3 and alternative B having a cost-benefit ratio of 1.9. It was also found that complying with AASHTO superelevation standards would result in a reduction of 1.2 crashes over 20 years with a total cost benefit ratio of 0.31. Shoulder alternative A was chosen out of the two alternatives, as there was limited funding for this project (*16*).

2.6.2. Kansas DOT

The Kansas Department of Transportation (KDOT) identified Kansas Highway 177 (K-177) from Council Grove to I-70 as a modernization priority. This project was provided a budget of $25 million, despite it costing $67 million to fully reconstruct the corridor, making this project a perfect candidate for PBPD.

Prior to project design, KDOT created a 19-member Project Advisory Committee to incorporate public input into the project. This allowed KDOT to understand affected users' safety concerns and priorities. Since KDOT found little to no operational issues, they focused this project on safety improvements.

K-177 goes through the Flint Hills, a scenic area that attracts tourists. These hills also cause embankment issues on the highway, with high slopes up to 1.5H:1V. Using the Transportation Research Board's Roadside Safety Analysis Program (RSAP), KDOT was able to determine the safety and cost benefits of different shoulder and clear zone widths throughout the different corridor sections. The results of these findings are summarized below in Figure 3.

Table 6.0 - Recommended Alternative

Alternative	Description	Length (mi)	Const. Cost (2017 Dollars)	Crash Analysis		Benefits							Carry Traffic Through
				Calculated Crash Rate	% Improvement	Shoulders	Roadside	Curves	Hills	Sight Distance	% Passing	% Improvement[a]	
Segment 1	ALT 1 [S, R]	2.61	$1,153,000	40.3	12.4%	X	X	-	-	-	52%	0%	X
Segment 2	ALT 6 [S, R, P]	0.49	$2,212,000	38.2	12.4%	X	0	0	0	0	0%	0%	X
Segment 3	ALT 2 [RC(E)]	2.50	$5,979,000	29.2	13.6%	X	X	-	X	X	99%	80%	X
Segment 4	ALT 1 [S, R]	1.62	$1,622,000	23.7	12.9%	X	X	-	-	-	60%	0%	X
Segment 5	ALT 1 [S, R]	3.08	$1,337,000	44.3	12.1%	X	X	-	-	-	48%	0%	X
Segment 6	ALT 4 [RC(O)]	1.58	$6,341,000	17.6	26.4%	X	X	X	X	X	100%	163%	-
Segment 7	ALT 1 [S, R]	2.74	1,027,000	28.1	11.4%	X	X	-	-	-	70%	0%	X
Segment 8	ALT 1A [S, R, C]	3.69	$2,803,000	58.8	11.6%	X	X	X	-	-	54%	0%	-
Segment 9	ALT 1 [S, R]	2.62	$2,300,000	27.1	11.3%	-	-	-	-	-	50%	0%	X
TOTALS			$24,774,000		13.1%						62%	14%	

Segment descriptions can be found in Table 4.3.

a $\%passing_{after} - \%passing_{before} = \%increase$

Key

S	Add Shoulders
R	Improve Roadside Conditions
RC(E)	Reconstruction - Existing Alignment
RC(O)	Reconstruction - Offset Alignment
SD	Improve Sight Distances
C	Improve Horizontal Curves
G	Guardrail Improvements
P	Partial Re-profile
B(E)	Bridge Improvements - Existing Alignment
B(O)	Bridge Improvements - Offset Alignment
SP	Special Improvements

Note: Refer to Table 4.3 for more information

Figure 3 - Final treatments for each section (17)

As is shown in the table, all sections were recommended for shoulder treatment and most sections were recommended for roadside improvements. It was found that the best cost savings and safety benefits resulted from 8-ft shoulders with 6:1 side slopes in the clear zone (*17*).

2.6.3. Minnesota DOT

Highway 10 is a major corridor in the Twin Cities area of Minnesota. A 7-mile stretch of the 4-lane divided highway northwest of Minneapolis was found to have 374 total vehicle hours of delay during P.M. peak periods in 2013 (i.e. the sum of the time that all vehicles experienced delay during the time period), as well as higher crash rates compared to similar facilities. This section of Highway 10 is highlighted in red in Figure 4 below.

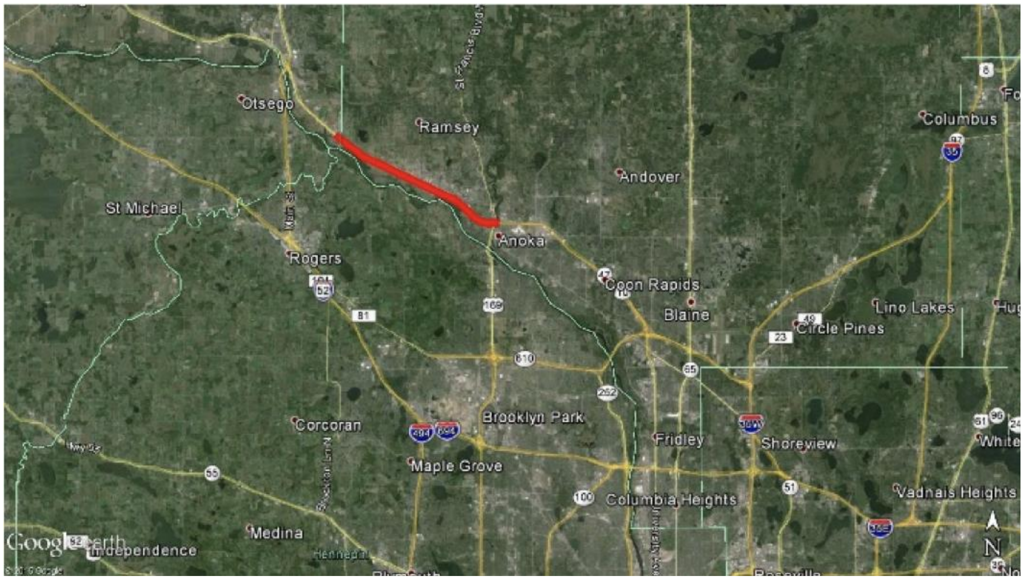

Figure 4 - Section of Highway 10 of interest (18)

It had been a goal to convert this section of 4-lane divided highway into freeway for quite some time; however, the project was not feasible due to limited budget resources and impacts to bordering properties. Instead, the Minnesota Department of Transportation (MnDOT) decided to consider lower cost alternatives instead of freeway conversion that would improve safety and operational performance.

This corridor has different contexts throughout this 7-mile stretch. On the west end, it is rural and agricultural. On the east end, it is suburban. Because of the roadway context, Highway 10 transitions from rural expressway, to signalized expressway, to suburban freeway from west to east.

The variation in roadway context led designers to have several different alternatives to a freeway conversion. The following improvement concepts were considered (*18*):

- Surface street extensions and new construction
- Restricted crossing U-turn intersections (RCUT)
- Right-of-way purchases
- Roadway realignment
- Revisions to left-turn treatments at T-intersections
- Construction of flyover ramps
- Construction of overpasses and underpasses
- Driveway removals
- Signal removal

These proposed safety improvements were evaluated using the Highway Safety Manual and were found to reduce crashes by 96% at only 50% of the cost of a full freeway conversion, primarily when implemented together. These safety benefits and cost savings are illustrated graphically below in Figure 5.

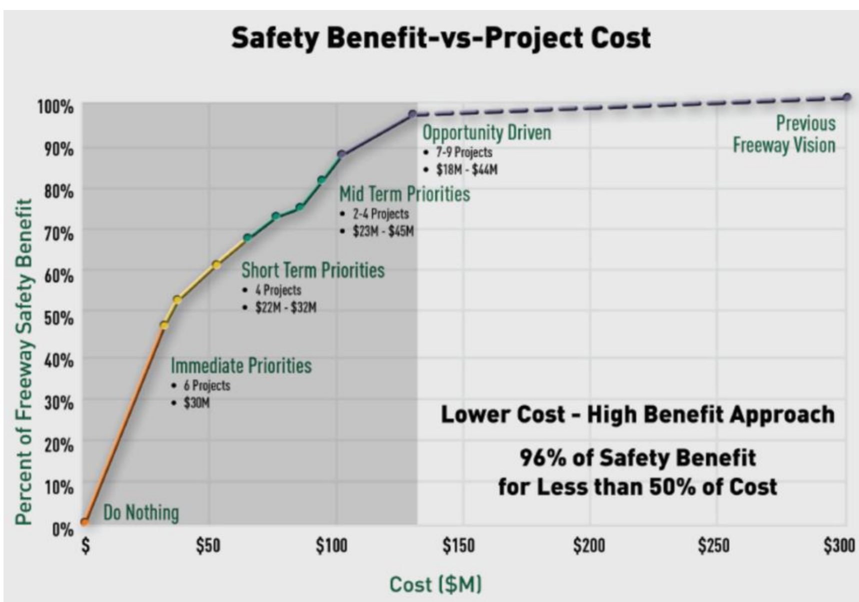

Figure 5 - Graph of safety benefit vs. project cost (18)

Additionally, the proposed safety improvements were analyzed using the software program VISSIM and FHWA's Microsoft Excel based Capacity Analysis for the Planning of Junctions (CAP-X) tool to determine their operational benefits. VISSIM was used to measure the improvements in traffic flow and CAP-X was used; "to evaluate the operational conditions of the innovative junction designs to provide planning level capacity assessment at each crossing" (*18*). It was found that by implementing these safety improvement projects, the corridor would see 90% of the operational benefits at 50% of the cost of a full freeway conversion. The operational benefit is shown graphically below in Figure 6.

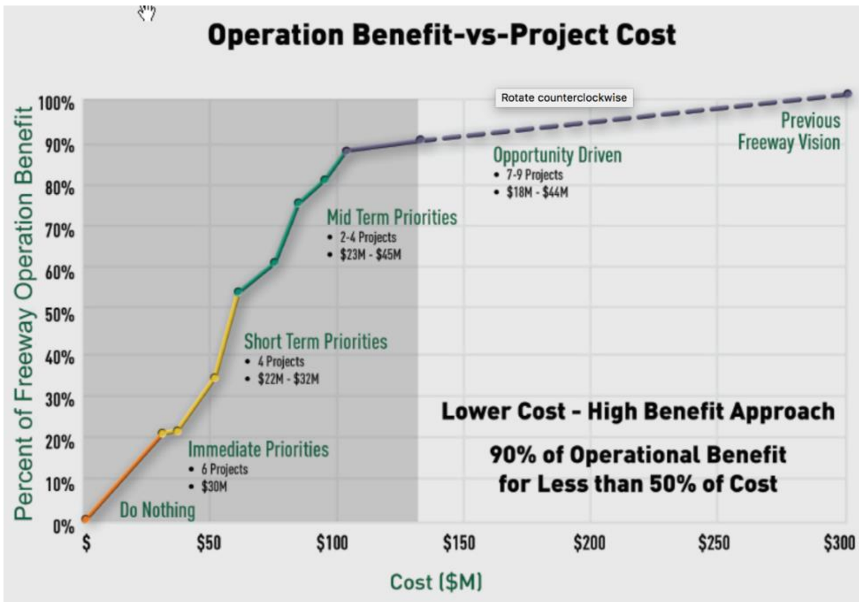

Figure 6 - Graph of operational benefit vs. project cost. (18)

3. Review of State DOT Guidelines For Performance-Based Practical Design

Numerous states have adopted PBPD principles to aid in project planning, project development, and alternative project solutions. A smaller subset of states has developed their own formal PBPD guidelines. In general, each guideline provides details of the degree to which Departments of Transportation (DOTs) are currently integrating PBPD into their project development processes. Ultimately, these guidelines are aimed at incorporating flexibility into the design process. This includes explicit consideration of environmental concerns, preservation of natural resources, and assessment of economic factors as a part of the roadway design process in addition to safety and operations.

This chapter summarizes existing PBPD guidelines for each state DOT. While these documents cover a similar range of topics, they also consider each DOT's needs, resources, and goals. In general, the more recently developed guidelines are more extensive and tend to promote public engagement and interdisciplinary teams to a higher degree.

Table 2 at the end of this section provides a high-level summary of these guidelines, including the overarching goals, as well as specific treatments and principles that are emphasized as a part of the agency's efforts to achieve PBPD. The remainder of this chapter synthesizes key elements of the guideline document for each of these eleven state DOTs.

3.1. Arizona Department of Transportation (ADOT)

ADOT developed a guidance document in 2019 called *"Guidance Principle for Performance-Based Design"* to provide flexibility and encouragement to professionals to help evaluate design decisions and alternatives diligently. The PBPD approach helps ADOT ensure that designs meet the project's objective and need to realize the most optimized performance of the roadway system. PBPD helps eliminate unnecessary constraints to designers by encouraging them to consider various factors when applying design criteria in developing a project. ADOT focuses on using PBPD in the design phase of a project.

All ADOT's projects are expected to apply the PBPD approach by making sure that (*19*):

- Project objectives and need statements that documents the department's performance objectives for the project are unambiguous.
- Decision making is performance-based and data-driven.

- The practical design methodology adopted results in the most cost-efficient solution and the output is such that it optimizes system performance and meets the project objectives.
- Design alternatives that address and support the project objectives and need are considered while focusing on maximizing system improvements.

PBPD helps ADOT to meet the project's performance objectives by encouraging designers to consider different factors in applying design criteria and removing constraints that may be deemed unnecessary.

ADOT has also defined the roles of its officials and technical team in the successful implementation of PBPD in its guidance document (*19*):

- Project managers are to ensure that decisions made regarding design aligns with the objectives, need, statement, scope, schedule, and budget of the project.
- Technical professionals such as engineers and consultants are to develop solutions and designs, meet the project objective and need statement, and document all decisions related to the design of the project and its development.
- Transportation Systems Management and Operations Division (TSMO) are responsible for the long-term operation and maintenance of the system.

ADOT has developed a PBPD process for the design phase of project development. They are mentioned below (*19*):

- A project and objective statement should be developed at the beginning of the project to clearly describe the goals and expected outcome of the project and not just a particular solution. This is important as it becomes easy to re-evaluate, remove, or eliminate any item that does not directly contribute to the objective and need statement.
- Projects should be designed to meet the project's objective and needs to achieve the best optimal performance of the roadway system.

3.2. Georgia Department of Transportation (GDOT)

GDOT developed a guidance document in 2021 called "*Practical Design Guide*" to provide information, education, and create a vision and foundation for the planning, programming, and designing of projects. GDOT defines PBPD as " the design that satisfies the need and meets the performance expectations for each project by utilizing the most efficient and cost-effective solution to solve or address the needs for the project" (*20*).

GDOT identified five components of practical design (*20*):

1. Project needs and goals
    - The establishment of the project's needs and goals helps in the development of the project justification statement. Clear identification of the goals and needs helps in establishing accurate and realistic total project costs.
2. Plan development process
    - Critical thinking is applied in meeting the project's stated needs and goals. This process is initiated at the planning stage and early program delivery steps where probable design solutions and realistic budget estimates are created.
3. Design criteria
    - Engineering judgment is applied. Flexibility for projects on existing roads, design variances, and design exceptions are encouraged.
4. Flexibility
    - To develop solutions that meet the needs and goals, incorporating flexibility in design standards and imposing engineering judgment is desired.
5. Value engineering
    - Value engineering is necessary from planning to construction. It involves the evaluation of a design by the project team in order to come up with an alternative solution that would meet the needs and goals of the project.

GDOT identified seven practical design metrics to develop efficient projects (*20*):

1. Reduction in project cost in general
    - Each component of the proposed project will be weighed against specific needs and purposes, resulting in the reduction or elimination of several design aspects, thus the project's average cost.

2. Reduction in major fluctuations of estimated costs throughout the life of a project

    - It is expected that the change in project costs during the design phase of the project should be reduced as the design is limited to the original purpose and need of the project.

3. Reduction in letting delays

    - Delay caused by right-of-way, utilities, environmental complications, or scope creep are expected to be minimized due to the identification and reduction of scope change throughout the design life of the project.

4. Reduction in the schedule for some types of projects

    - The use of a more focused purpose and need is expected to eliminate scope creep leading to a general reduction in the amount of time spent on the design phase.

5. Increased implementation of flexibility through an increase in the number of design exceptions (DEs)/design variances (DVs)

    - The departure from standard and rigid designs is expected to significantly increase the number of design exceptions and variances submitted for each project.

6. Increase in program safety

    - Adherence to the stated purpose and need of a project would reduce the overall costs, thereby allowing more flexibility in the application of the remaining funds to improve features with a higher cost-benefit ratio.

7. Greater benefit-cost per project and/or design feature

    - The reduction in a project's overall cost due to adherence to the stated purpose and need is expected to increase the benefit-cost of the project.

3.3. Idaho Transportation Department (ITD)

The ITD published a manual in 2007 named "*Practical Solution for Highway Design*" that provides guidance to implementing PBPD. ITD frames PBPD as a mechanism to; "… challenge traditional standards and to develop safe and efficient solutions to solve today's project needs." The main goal of practical design is to build cost-effective projects so that a good, safe and efficient transportation system can be achieved (*21*).

To reach the goals set by ITD, the project scope must be appropriately defined by meeting the project's purpose and need. Attention must also be paid to the location of each project. Sensitivity to the project's location will help in the implementation of standards suited to the surrounding.

Two themes stand out in ITD's practical solution guidance document:

- The life cycle must be considered without shifting the burden to maintenance.
- Safety should not be compromised.

The primary guidance provided by ITD are (*21*):

- The facility type chosen should fulfill the purpose and need of the corridor as a whole.
- The speed used in the design should be the posted speed or as deemed appropriate for the project purpose and need.
- The community must be involved from the beginning and designs must respect community values.
- Congestion does not necessarily need to be eliminated as moderate congestion promotes more efficient use of the facility by promoting carpooling or other means of transportation.
- Rural locations should accommodate the 20-year peak hour traffic at a Level of Service (LOS) of D, and off-peak Level of Service C. Urban roads should be LOS E for peak and LOS D for off-peak.
- The facility should provide a balance between access and mobility for its intended purpose.
- If a four-lane facility is required to satisfy the required Level of Service, it should be designed as an expressway unless a freeway[1] is made mandatory.

Guidance was also provided for Transportation Planning and Roadway Design Elements (*21*):

- Transportation Planning

[1] While the terms "expressway" and "freeway" are often used interchangeably, an expressway is a divided, limited-access facility which may have occasional at-grade intersections, while freeways are constructed to a higher standard with grade separated interchanges.

- Design speed
- Interchanges/at-grade intersection
- Two-way left turn lanes (TWLTL)
- Passing lanes
- Roadway design elements
- Lane width
- Shoulder width
- Horizontal and vertical alignment
- Rumble strips
- Guardrail
- Pavement structure
- Bicycle and pedestrian facilities
- Property right of way
- Processed materials such as aggregates, asphalt, and cement
- Traffic control

3.4. Indiana Department of Transportation (INDOT)

INDOT developed a manual in 2014 named "*Open Roads: Practical Design for Transportation Project Delivery*" to help strengthen INDOT's "ability to plan, build, maintain, and operate an excellent transportation system for the benefit of the residents of Indiana". This manual outlines the implementation of INDOT's practical design initiative and provides suggestions on the practical design process (*22*).

The open roads manual can be described as both a product and a process. This manual focuses on solutions that improve the operational and safety performance of the entire roadway system instead of working to achieve the fastest solution or a specific solution. Further it also encourages for innovation and flexibility and supports detailed analysis while selecting a solution to a transportation problem (*22*).

The manual requires a simple process for noting and approving the rationale behind design choices as well as a clear statement of purpose and need.

Open Roads is established on four principles (*22*):

1. Sound engineering judgement

- Reliance on the application of sound engineering judgment, common sense, context awareness and sensitivity, and innovation when considering design alternatives and solutions.

2. "Design up" philosophy

   - The designer should consider the existing condition of the facility as the baseline condition and design up from that point to meet the projects' purpose and need rather than starting with the desirable condition and then forced to remove items to meet the scope and stay within budget.

3. Get the scope right

   - The purpose and need statement for every project should be appropriately defined and documented such that the problem to be solved and the future goals of the system are correctly specified. This will help identify items that do not directly support the purpose and need to be re-evaluated, redesigned, or eliminated.

4. Safer system focus

   - Optimizing the condition and performance of the corridor should be the focus rather than attempting to achieve individual project perfection. All projects should be as safe or safer than the existing condition.

3.5. Kansas Department of Transportation (KDOT)

Since 2009, KDOT started taking proactive measures to incorporate PBPD principles into design and project development. KDOT developed a "*Practical Improvements"* manual in 2009, with an intention to "stretch our transportation improvement dollars further while still maintaining a safe and efficient highway system" by combining flexibility within current standards and evaluating alternatives outside those standards (*11*).

Practical improvement is considered at all stages of project development, from scoping to construction, and is achieved by formulating and evaluating alternative solutions for the project's design. There must be a balance of safety and cost with scope for each alternative solution, as shown in Figure 7 below.

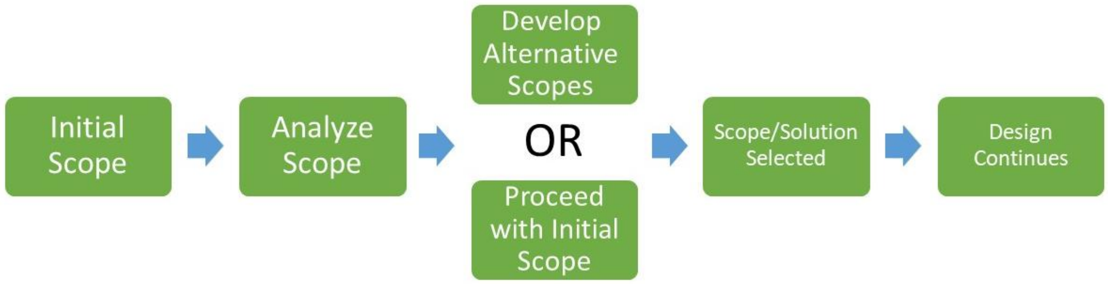

Figure 7 - The process of achieving scoping (11)

In formulating balanced alternative solutions, the project scope must be determined. An initial scope can be developed for project programming, the scope could then be investigated further, and possible alternatives can be developed. The alternatives could then be evaluated and compared, and the best one can be selected.

Some of the considerations made at each point of scope development are (*11*):

- Analyzing the scope. This involves knowing:
    - The main purpose of the project being proposed.
    - The present conditions of the roadway and the need for an upgrade and modernization.
    - How the initial scope compares with the existing roadway facilities and with the proposed enhancements to the adjacent roadways under evaluation.
    - The amount of funding available.
- Developing alternative scopes (*11*)
    - It should begin with the review of current design standards and criteria such as AASHTO.
    - Use criteria values outside of the existing criteria ranges which may involve writing and granting a design exception.
    - Guidance on developing alternative scopes has been provided for roadway shoulders and roadside elements, drainage structures, facility types, traffic handling and accommodation, and environmental process.
- Comparing alternate scopes (*11*)
    - Consideration is made as to how each proposed scope balances cost, operations, environmental concerns, stakeholder input, and safety.
    - The limits of available funding and the value of investing funds for future needs should also be put into consideration when comparing the scopes.

How well each scope does in relation to the analyses performed on the scope will determine the scope that would be chosen.

3.6. Kentucky Transportation Cabinet (KYTC)

KYTCs memorandum on "*Practical Solutions*" which was issued in 2008 to provide guidance on the implementation of practical solutions at all decision-making stages of all phases of project development and delivery. The guide is intended to help project teams realize the task of addressing purpose and need while ensuring that the project scope and design remain within the boundaries of limited resources. The fundamental principle of practical solutions is to; "balance operational efficiency, safety, project constraints, and cost" (*23*).

In 2008, KYTC produced a study titled *Practical Solutions Concepts for Planning and Designing Roadways in Kentucky*, focusing on project development, planning, and design stages.

The study proposed several principles to achieve a successful practical design (*23*):

- Target the goal/objectives of the purpose and need statement
    - The purpose and need statement should serve as the primary goal and not the lowest acceptable threshold of performance.
    - The purpose and need statement should be such that it establishes the existing conditions and the prevailing constraints on the project.
    - The purpose and need statement should be refined with disaggregated data in order to highlight specific problem areas that need to be addressed.
- Meet anticipated capacity needs.
    - Level of Service (LOS) alone should not be the only determining factor in determining the capacity of the roadway; instead, it should be measured to assure that the correct size design is provided.
- Evaluate safety compared to the existing conditions.
    - Re-establish the understanding of safety improvements by using safety models to predict safety performance.
    - Compare safety evaluations with existing conditions rather than among other similar site conditions.
    - Use safety models in predicting the safety performance of a roadway.
- Develop and evaluate design options and alternatives.
    - Address specific problems and needs by customized design rather than importing solutions from problems that look similar.

    - Clearly state and define the underlying problem.
    - Have all design options and alternatives available.
- Maximize design to the point of diminishing return.
    - Project designers should use innovative designs to address constraints that involves topographical, environmental, historical, existing infrastructure, and budgetary issues.
    - Operational considerations should be viewed in terms of diminishing returns.
    - A designer needs to consider all proposed design elements and the point of diminishing returns associated with each to determine the best possible solution.

3.7. Minnesota Department of Transportation (MnDOT)

MnDOT developed a guidance document in 2018 called "*Performance-Based Practical Design: Process and Design Guidance".* Practical Design is seen as an approach that prioritizes the economy and seeks to optimize return on capital investment. In contrast, "performance-based design involves determining design features to achieve desired outcomes and solve identified problems based on known effects of physical roadway features on actual performance by encouraging the optimization of return on investment, consideration of alternative scopes and design value, the use of evidence-based techniques, financial sustainability" (*24*).

The combination of Practical Design and Performance-Based Design results in Performance-Based Practical Design (PBPD). PBPD uses performance-based methods and processes to solve problems and produce results while recognizing limited resources and the need to spend public funds wisely and with a long-term, systemwide outlook.

The manual list PBPD process steps as (*24*):

- Intended project outcomes
    - Performance characteristics: It represents the difference between the traditional dimension-based design approach and PBPD. PBPD's focus is on the actual functional performance of the system. Prominent performance characteristics which need to be focused on to achieve the desired performance are: quality of service, safety, reliability, accessibility, infrastructure integrity, ease of use, ease of maintenance, visual quality, fit to context, and community.
    - Project purpose, need, and problem: Knowing a corridor's needs, purpose, and problems is crucial for setting project scope and design.

- Desired outcomes and goals: An unambiguous statement of what is being achieved in a project is essential to developing a design that will achieve it.
- Designing to achieve intended outcomes
    - This involves using PBPD methodologies and data to determine the anticipated performance associated with scope elements, design features, configurations, and concept alternatives. The performance outcome should be such that it results in cost savings that achieve performance improvement and solves problems within the bounds of practicality and context sensitivity.

Some design criteria are presented within the guidance (*24*):

- Level of Service (LOS)
    - Rather than considering LOS as a design standard or criterion, it should be regarded as a performance measure.
    - LOS should be considered one of many attributes to right size instead of trying to provide the highest LOS possible.
    - Future-year micro-level LOS calculations should not be focused on; instead, the focus should be on corridor-length travel time.
    - Vulnerable road users LOS should be computed where the volume of non-motorized traffic is significant (though significance may be based on multiple factors).
- Design speed
    - Design speed should be viewed as a choice and does not need to be equal to the anticipated posted speed.
    - Design speed selection should be based on context and practicality rather than the posted speed.
    - In most cases, a design speed less than the posted speed will be the most appropriate choice, and this should be considered as conventional practice for urban and suburban streets.
    - Context, terrain, functional class, and economy should be the basis of design speed selection on rural two-lane highways.

MnDOT has also provided guidance on design vehicles, cross-sectional elements, roadside design, sight distances, and alignment elements.

3.8. Missouri Department of Transportation (MoDOT)

MoDOT developed a Practical Design document in 2005 named "*Practical Design, Meeting our Customers' Needs"*, whose goal is to "build good projects, not great projects, to achieve a great system." (2). When considering cost savings, lifecycle costs are also considered.

MoDOT saw the need for a dual approach to implementing practical design: "The first step was to develop best practices to encourage staff to think outside the box as they designed future improvement projects to provide the best value for the taxpayers. The second step was to adopt new policies in areas most affecting improvement costs" (2).

There are three main principles MoDOT is using to achieve PBPD (2):

1. No compromise with safety.
    - Every project must make the facility safer after its completion, as PBPD is not an excuse for compromise to be made in the safety of transport facilities.
2. Collaboration on the transportation solution.
3. The design speed will equal the posted speed
    - MoDOT will not design a road above its posted speed. This will ensure that adequate savings are made from the design stage to the construction stage.

MoDOT provides guidance for the implementation of PBPD on the facility type. These are further subdivided into facility selection, at-grade intersections, and interchanges. Guidance was also provided for section elements, and this was subdivided into lane width, shoulder width, median width, in slope grade, backslope grade, and roadside ditches. Guidance for horizontal and vertical alignments was also provided. The guidance for pavement was subdivided into paved shoulders, bridge approach slabs, and pavement.

Structures and hydraulics guidance was subdivided into bridge width, bridge and culvert hydraulic design, and seismic design. Roadside safety guidance included guidance on rumble strips and guardrails. Guidance for disposition of routes, bicycle facilities, pedestrian facilities, embankment protection, borrow and excess earthwork, minimum right of way width, and design exception all fell under the incidental/miscellaneous section of the guide.

Type of facility and guidance (2):

- Facility selection
    - For major and minor routes, the type of facility will depend on the desired Level of Service (LOS) given the 20-year traffic projection of the corridor and should represent a balance between access and mobility.
    - When the desired LOS requires a four-lane facility; it will be designed as an expressway unless a freeway is mandated and two-way left-turn lanes (TWLTL) are permissible where practical.
- At-grade intersections
    - For an expressway that passes through communities, signalized intersections can be considered but not in rural areas unless in an exceptional circumstance.
    - The criteria for determining the minimum distance between intersections along roadways is linked to the classification of the roadway (major or minor) and whether the road is urban or rural.
- Interchanges
    - An interchange is to be considered when it is warranted by the 20-year design traffic projection or safety concerns, and two miles and five miles are the desired spacing in interchanges in urban and rural areas, respectively.
- Section elements and guidance
    - Lane width on major roadways should be 12-ft wide and between 10-ft to 12-ft on minor roads, depending on the traffic volume.
    - Shoulders should never be eliminated, and they should be between 4-ft to 10-ft on major roads and 2-ft to 4-ft on minor roads.
    - A depressed median of a width of 60-ft should be the preferred section for a freeway and expressway.
    - The slope ratio that is not be exceeded should be included in the geotechnical report.
    - The depth of roadside ditches should be sufficient to ensure drainage from the design storm event.
    - In areas determined as erosion-prone, necessary erosion control methods will be used.

- Horizontal and vertical alignment guidance
    - The anticipated posted speeds should be a major determinant of horizontal and vertical alignments.
- Pavements and guidance
    - The entire shoulder width should be paved on major road sand aggregate stabilized on minor roads unless exceptional circumstances exist.
    - The pavement thickness will be determined by the Construction and Materials Division for all projects on major roads.
- Rumble strips
    - Shoulder rumble strips should be present on all major roads, and centerline rumble strips should be present on all major 2-lane roads with new pavement.
- Incidental/miscellaneous
    - Pedestrian facilities should be separated from the traveled way by a barrier curb in developed areas, and it should have a minimum width of 5-ft and thickness of 4-in.
- Design exception
    - Designers are encouraged to seek design exceptions wherever the potential for additional value lies outside of written engineering policy.

3.9. Oregon Department of Transportation (ODOT)

The ODOT's "*Design Standard Policies and Processes"* was published in 2012 to replace the "*Practical Design Guidebook"* published in 2010 and highlighted the philosophy of ODOT in the implementation of practical design. ODOT sees practical design as a strategy to establish appropriate project scopes that fits specific project purpose and needs. A systematic approach is adopted to optimize the transportation system to use limited resources efficiently. ODOT believes that; "practical design requires engineering judgment, a complete focus on the project's purpose, safety evaluation and design operations, and documentation of design decisions" (*14*).

The three major goals of practical design as defined by ODOT are (*14*):

1. To direct available dollars towards activities and projects that optimize the system as a whole.
2. To develop solutions to address the purpose and need identified for each project.
3. To design projects that make the system better, address changing needs, and maintain current functionality by meeting, but not necessarily exceeding, the project defined purpose, goals, and need.

ODOT has identified five fundamental values that form the foundation of its practical design program. These are (*14*):

1. Safety: Overall system safety should not be compromised, and every project should make the facility safer or maintain the existing safety level for that facility.
2. Corridor context: A corridor approach should be used in establishing and evaluating design criteria. The unique features of the project and how it fits with other parts of the corridor and the natural and built environment should be put into consideration.
3. Optimize the system: An asset management approach should be adopted to manage individual infrastructure to optimize the lifecycle investment in the asset. This would ensure that the highway system is maximized for safety, mobility, and financial investment by balancing the trade-offs between competing goals.
4. Public support: Public trust is a cornerstone of ODOT's practical design program as it believes that working in partnership with local communities will help in shaping the chosen solution, and consideration will be made to vulnerable road users.
5. Efficient cost: Funds should be stretched as much as possible and considered in the project development process to meet the desired purpose. Practical design involves applying the appropriate standard to the critical elements to meet project-specific needs. This ensures that funds are redistributed from items that are not high priority to a project or to other projects that benefit the system. Practical design stresses the importance of making the best strategic decisions that will benefit the overall system.

3.10. Utah Department of Transportation (UDOT)

UDOT published a Practical Design Guide named "*Planning and Designing Practical Transportation Solutions for Utah"* to facilitate PBPD process in Utah. UDOT defines the goal of practical design as; "the appropriation of scarce resources to maximize system-wide improvements by focusing on improvements that maximize the roadway system as a whole rather than maximize improvements at a few locations" (*15*). UDOT phrased the practical design approach as "building a series of good not great projects will result in a great system".

UDOT's four overarching goals to focus on all improvement projects are listed as (*15*):

1. Taking care of what UDOT currently has
2. Making the system work better
3. Improving safety
4. Increasing capacity

Most important to UDOT's concept is to avoid diminishing returns. Investors must identify the point at which returns on roadway investments become an inefficient use of funds. Additionally, all improvement projects must meet the project's objective statement and practical design goals to help determine this point of diminishing returns.

From UDOT's perspective, practical design is a design up approach where the goal of the project is to meet the project's objective statement rather than have a particular solution.

UDOT has identified three practical design goals (*15*):

1. Optimize the transportation system as a whole: This will help to provide a big picture approach to planning the general size, scope, and funding of transportation projects to guide all project-level practical design decisions. This would be achieved by:
    - Continuous prioritization of a list of improvements and directing available funding towards appropriate projects.
    - Giving a clear understanding of how projects fit into the roadway system to project teams and making clear that corridor priorities are the driving force behind each project.
    - Providing project teams with a clear understanding of the project's objective statement and corridor context.
    - Communicating corridor and systemwide knowledge to the project team.
    - Emphasizing analyses, such as the operational system report, during the development of alternatives.
    - Demonstrating how the design optimizes the road system as a whole.
2. Meeting the goals of the objective statement identified for each project: Projects should trackback to the defined priorities and objectives of the system and corridor. All

proposed improvements should be monitored to meet the objective statement and not necessarily exceed it. This would be achieved by:

- Focusing on improving the project limits to a level that meets the objective statement.
- Granting waivers, exceptions, and deviations when necessary to meet the project objective sufficiently.
- Developing designs that meet the objective statement and corridor priorities.

3. Designing the most efficient method (cost and function) to achieve the objective statement: Every improvement proposed should look to achieve the most return for the least cost. This could be achieved by:
   - Focusing on the maximization of cost savings while meeting the objective statement.
   - Evaluating life cycle costs.
   - Eliminating over-design costs by focusing on building-up from the existing condition.
   - Ensuring that the value of every improvement to the corridor and system is questioned.
   - Ensuring that project resources are saved for use on additional improvement projects or other locations.

To UDOT, the objective statement of a project is of utmost importance, as it is the basis of developing projects to improve the entire network. An objective statement defines the needs and goals of a project. If a project does not meet its objective statement, it must be redesigned or removed. Additionally, the objective statement should evolve with the project to meet site and network needs.

Some of the key elements of the objective statement are (*15*):

- Defining the objective statement in terms that the general public can easily understand.
- Presenting the information such that it is as comprehensive and specific as possible.
- Being factually and numerically based.
- Being stated in a concise and clear manner.
- Being stated as an expected positive outcome.
- Addressing UDOT's four overarching goals.

UDOT has identified some performance measures for practical design implementation. The indicators are (*15*):

- Total cost savings for the overall program
- Percent savings for the overall programs
- Percent savings per project
- Percent of projects using practical design
- Percent savings by project type
- Percent savings by project size

3.11. Washington State Department of Transportation (WSDOT)

WSDOT revised the "*Moving Washington Forward: Practical Solutions"* in 2020 through an executive order E 1090.01 to ensure that the policy applies to everything the agency does. According to WSDOT, practical design uses appropriate performance metrics, stakeholder inputs, and agency risk management practices to help identify investments that address a given problem in the most efficient manner possible. Practical design is seen as the design phase of practical solutions whose goal is to help in the identification of low-cost solutions that meet needs while considering benefits that the system derives as a whole and the role of "... incremental solutions to address uncertainties identified in future scenarios" (*4*).

WSDOT uses the Basis of Design (BOD) template to document practical design approach in either the project scoping or design phase, and the process consists of seven steps (*4*):

4. Assemble a project advisory team:
    - An advisory team that possess the skills, knowledge, and responsibilities for design decision-making should be assembled.
- Identification of baseline needs in terms of performance, contributing factors, and underlying reasons:
    - The primary reason for a project being at a particular location can be described as the project's need. Performance metrics should be determined based on the assessment of the specific need of a project and other contextual needs obtained through engagement with the project host community. The need can be refined by performing contributory factor analysis.

- Identification of the land use and transportation context for the location:
    - This involves the activities, functions, and characteristics within a geographical area. However, the WSDOT context determination process involves current and future land use and transportation conditions.
- Selection of design controls that are compatible with the context:
    - Highway design is constrained by control design. WSDOT has listed five design controls that could help in making design decisions.
        - Design year
        - Modal priority
        - Access control
        - Design speed
        - Terrain classification
- Formulation and evaluation of potential alternatives:
    - Developing a solution for the baseline need at the lowest possible cost should be the goal. To support this goal, the TSMO has provided potential operational and demand management strategies that could be assessed before capacity expansion.
- Selection of design elements that will be part of the alternatives:
    - The design element selection is entirely based on the option chosen to address the baseline need while still balancing performance trade-offs.
- Determination of design element dimensions that are consistent with the context, performance needs, and design controls.

The tools used to document decisions and analyses in the creation of solutions are basis of design (BOD), basis of estimate (BOE), design parameter sheets, and alternative comparison tables.

3.12. Summary

The common theme of all state's DOT practical design guidance document can be stated as:

- Safety should not be compromised for any reason.
- Project needs, goals, purpose, and objectives need to be clearly stated for the successful implementation of PBPD.
- Focus should be on the transportation system as a whole, rather than on individual projects.

Table 2 shows the summary of all the state DOT guidelines reviewed as a part of this study.

Table 2 – Summary of state DOT guidelines reviewed

State DOT	PBPD Document/ Year	Overarching Goal	Treatments/Principles
Arizona Department of Transportation (ADOT)	Guidance Principle for Performance-Based Design in 2019	To provide flexibility and encouragement to professionals to evaluate design decisions and alternatives diligently.	Maintaining natural environment; community needs; safety; healthy economy.
Georgia Department of Transportation (GDOT)	Practical Design Guide in 2012	Maximize the benefit to the entire transportation system, not to a single project.	Safety improvement is recognized as a priority, overall project cost and delivery time is reduced.
Idaho Transportation Department (ITD)	Practical Solutions for Highway Design 2007	To build cost-effective projects to achieve a sound, safe, and efficient transportation system.	Provision of primary guidance for several design elements with design speed and Level of Service (LOS) the most important.
Indiana Department of Transportation (INDOT)	Open Roads: Practical Design for Transportation Project Delivery 2014	To improve a corridor's overall condition and function rather than perfect individual projects.	Sound engineering judgment, adoption of "design up" philosophy, a commitment to getting the scope right, and a safer system focus.
Kansas Department of Transportation (KDOT)	Practical Improvements 2009	To stretch transportation improvement dollars further while still maintaining a safe and efficient highway system.	Project scoping is considered an integral part of the process. Alternative scopes may involve selecting design criteria outside of the prevailing criteria range.
Kentucky Transportation Cabinet (KYTC)	Practical Solutions 2008	To find a way to do more with less.	Identify the project purpose and need, which drives the project scope.
Minnesota Department of Transportation (MNDOT)	Performance-Based Practical Design: Process and Design Guidance in 2018	To follow PBPD principles in all the transportation projects wherever possible.	Engage stakeholders; safety; encourage multimodal transportation; respect the environment.
Missouri Department of Transportation (MoDOT)	Practical Design, Meeting Our Customer's Needs in 2005	To build good projects, not great projects, to achieve a great system.	Define project scope by focusing on achieving the project purpose and need.
Oregon Department of Transportation (ODOT)	Practical Design Guidebook	To direct available funds to projects that optimize the system as a whole.	To follow design practices that incorporate the maximum flexibility in the application of standards to reduce cost while preserving and enhancing safety and mobility.
Utah Department of Transportation (UDOT)	Practical Design Guide in 2011	To maximize improvements to roadway systems rather than privileging a small number of projects whose benefits have limited reach.	Practical Design is a "design up" approach, not a strip-down process.
Washington State Department of Transportation (WSDOT)	Design Manual M 22-01.20, 2021	To identify low-cost solutions that meet the needs while considering benefits to the system as a whole.	Basis of Design (BOD) is used to document practical design approaches. It consists of community engagement, assembling an advisory team, needs and performance identification, and others.

4. STATE DOT SURVEY ON PERFORMANCE-BASED PRACTICAL DESIGN

A questionnaire survey was developed by the research team and reviewed by the team and Research Advisory Panel during the summer of 2021. The objectives of the survey were to: (a) identify existing policies, practices, and guidance to the application of PBPD, (b) prepare an inventory of performance measures commonly used by agencies in implementing PBPD, and (c) determine the resources that are utilized in estimating and forecasting the potential impacts of PBPD across various performance measures. The survey was distributed in a hard copy format, as well as electronically via the Google Forms platform, on August 26, 2021. The distribution list included all members of the AASHTO Committee on Design, as well as the AASHTO Committee on Safety. A total of 21 states responded to the survey and a map of the responding DOTs is included in Figure 8.

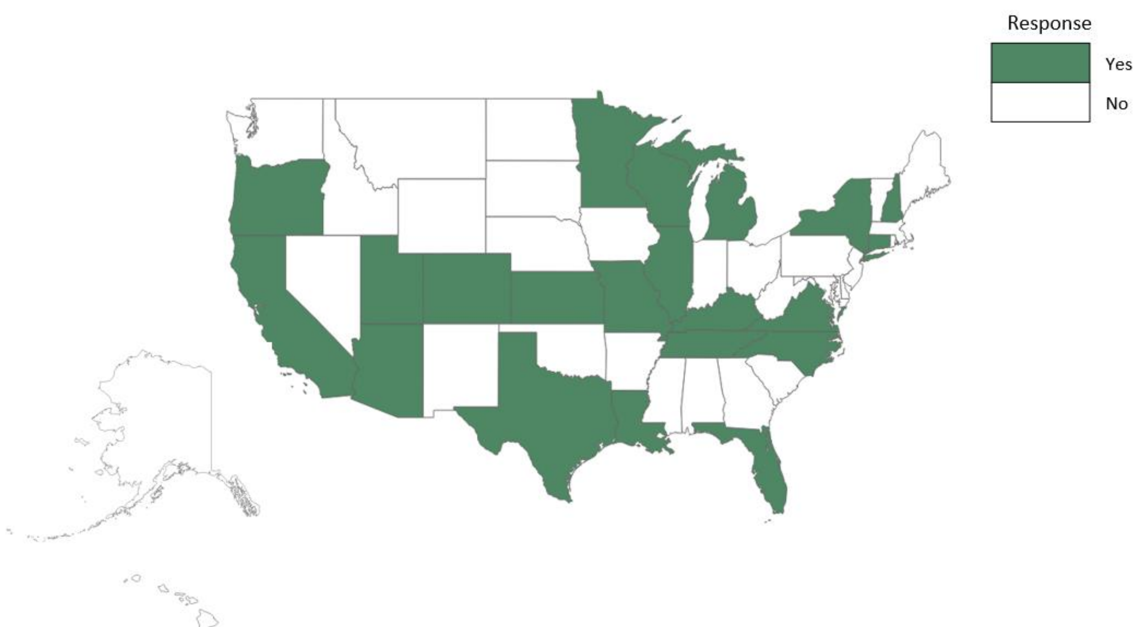

Figure 8 – State DOT survey responses.

The survey preceded with survey information and objectives followed by respondents' contact information for further follow-up. A total of 19 questions were included in the survey, along with file upload capability. The survey questionnaire is included in Appendix A. The following section summarizes the survey findings.

Question 1. Does your agency's existing guidance and regulatory requirements allow for PBPD or similar practices?

Figure 9 shows agencies response when asked whether there were any existing guidance or regulatory requirements which allowed for PBPD or similar practices in place. Most of the agencies identified that they have a form of guidance or regulatory requirements existed, and only 5 percent of the agencies responded negatively. However, when asked if the agency has a formal or informal program related to PBPD, only 38 percent indicated formal implementation of PBPD program. In comparison, 43 percent were informal, and the remaining 19 percent responded with "no" to PBPD-related program implementation (see Figure 10).

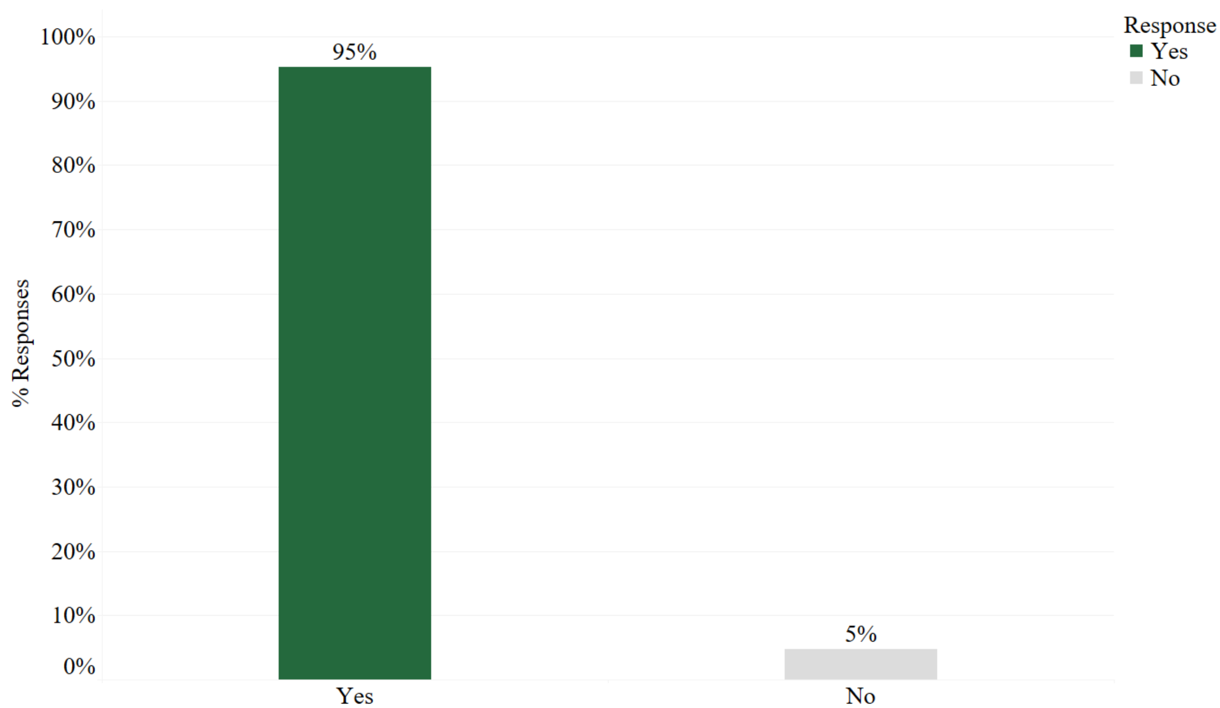

Figure 9 – Does your agency's existing guidance and regulatory requirements allow for PBPD or similar practices?

Question 2. Given the definition provided, does your agency have a formal or informal program related to PBPD, or some other similar project development and design philosophy?

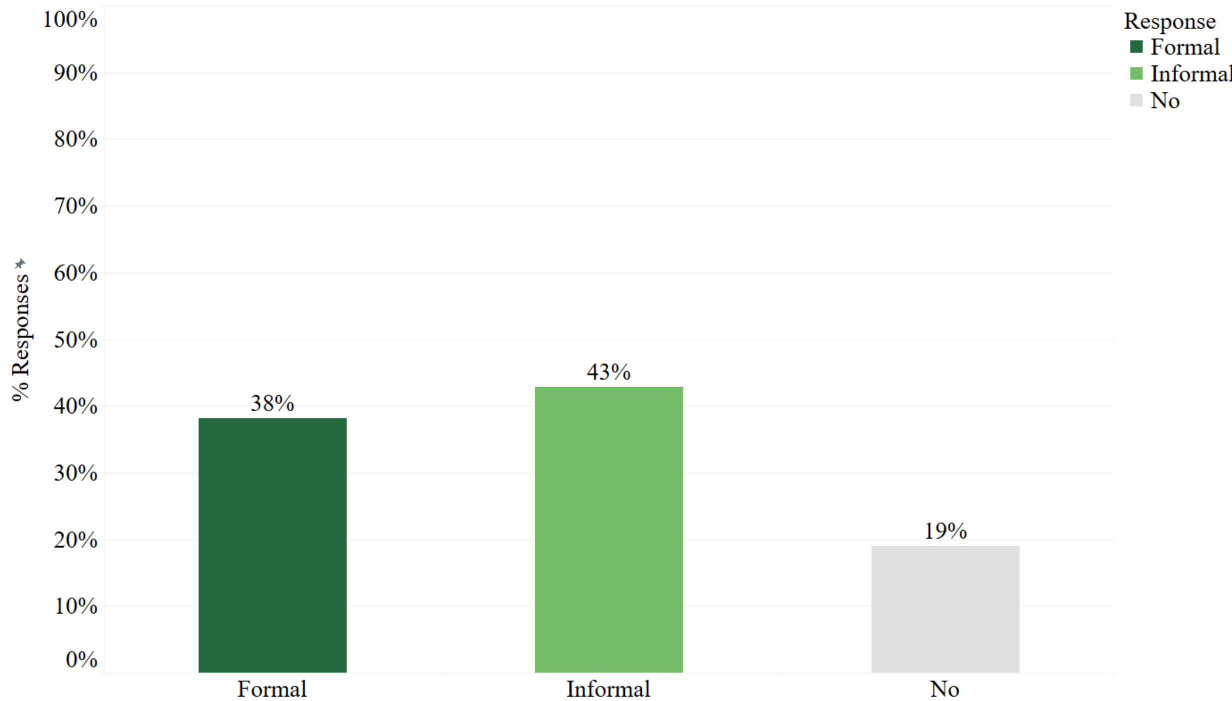

Figure 10 – Given the definition provided for PBPD, does your agency have a formal or informal program related to it, or some other similar project development and design philosophy?

Question 3. Please describe how PBPD decisions are made and documented at your agency (e.g., who has the authority to make decisions, what types of documentation are required)?

Then, agencies were asked to describe how PBPD decisions are made and documented. The answer varied between agencies. Table 3 shows in brief who has the authority to make decisions and how they are documented for each state. In general, PBPD related decisions are made in the early design process of the project and all decisions made are reported to be documented. Decisions are initially made at the district level (Florida DOT) or regional level (Oregon DOT and Wisconsin DOT) and may also require approval at the state level (Minnesota DOT). The Colorado DOT indicated that the engineer in charge takes the decisions and decides the documentation needed. For Illinois DOT, the PBPD document is currently in the draft phase; however, the project needs assessment and project scoping is done at the start of project where pavement condition, safety, capacity, etc., are considered. Kansas DOT stated that decisions are governed by cost-effectiveness and the benefit-to-cost ratio analysis of the project. Some of the indicators that are considered within the calculations are driver time delays, vehicle wear and tear, agency savings, and maintenance cost. In Michigan, MDOT reported that PBPD is generally considered a design exception process (similarly to Caltrans). The road design engineer takes a decision and provides details of deviations and rationale behind it. Both Caltrans and the KYTC indicated that the project development team and stakeholders make decisions at the project level and are documented in the project report. At the same time, the Louisiana DOT also indicated that design exceptions require the approval of the chief engineer and are documented in the design reports; PBPD decisions are made at the feasibility and environmental phase and are recorded. Tennessee reported that road safety audits and spot safety improvements govern the decisions where traffic crash reports, the Highway Capacity Manual, and project purpose and needs are referred.

Table 3 – How PBPD decisions are made and documented at your agency (e.g., who has the authority to make decisions, what types of documentation are required)?

Agency/Department	Who has the authority to make decisions?	What types of documentation are required?	Others
Arizona DOT	Planners, designers, and technical staff.	Technical staff evaluates design alternatives and document decisions in technical reports.	NA
Caltrans	Project development team and stakeholders.	Documentation includes capturing decisions in project report.	PBPD is referred as design exception.
Colorado DOT	Engineer in responsible charge	Engineer in responsible charge decides the documentation needed.	NA
Connecticut DOT	None at this point	None at this point	NA
Florida DOT	District level through the multi-disciplined project scoping team. Generally District Design Engineer takes decision.	Each stage of Planning, design, construction and maintenance are documented.	NA
Illinois DOT	Project development team	Pavement condition, safety, capacity, etc. are considered.	PBPD in draft phase.
Kansas DOT	Designers and Engineers	Decisions are governed by cost-effectiveness and B/C ratio. Also consider- driver time delays, wear and tear on car, etc.	NA
KYTC/Division of Highway Design	Project development team.	Purpose and need statement are required and are documented in design executive summary.	NA
Louisiana Department of Transportation & Development	Chief engineer (and possibly FHWA)	Design reports and design exception process	PBPD decisions made in feasibility and environmental phase and is documented in related documents.

Agency/Department	Who has the authority to make decisions?	What types of documentation are required?	Others
Michigan DOT	Engineer of road design	Design reports	PBPD is considered a design exception process
Minnesota DOT	State Design Engineers and Central office	Geometric design layouts	NA
Missouri DOT	Core practical team	Project reports	NA
New Hampshire	Project manager and team	Project reports	PBPD is applied when a green book compliant design is not feasible.
New York State DOT	Project manager and team	Influenced by Value Engineering and design exceptions	NA
North Carolina DOT	None at this point	None at this point	NA
Oregon DOT	Regional planners and technical center staff	The urban design concurrence (UDC) form is used for design decisions.	NA
Tennessee DOT	Chief engineer and chief of environment	Road safety audits and spot safety improvements govern the decisions. Traffic crash reports, HCM, project purpose and needs are referred.	NA
Texas DOT	Lead engineers	Documentation is done for alternative analysis, environmental considerations/mitigation/clearanc e.	NA
Utah DOT	Project manager, program manager, and region director.	All the decisions are documented in project definition document.	NA
Virginia DOT	Chief engineer	Decisions are made early in the process at pre-scoping and scoping, and documented in project specific scoping documents.	NA
Wisconsin DOT	Region project development chiefs	Project report	Decisions are made through PBPD tool, generally project description and need, existing and proposed facility information and traffic volume information are needed.

Question 4. Please describe how PBPD decisions are approved at your agency (i.e., what does the approval path look like and who at the agency is involved)?

Regarding the decisions and documentation of PBPD, states reported that PBPD approval for projects ranges from planners or engineers to a multi-disciplined project scoping team, as shown in Table 4. However, PBPD decisions are generally included in the initial process of the project. Virginia and Arizona DOT specified that the PBPD scope is included in the project planning and scoping. At the same time, Kansas DOT applied PBPD based on cost-effectiveness (a cost to benefit ratio) analysis which considers the road user convenience (delays, vehicles wear and tear, etc.) and construction cost and maintenance. MDOT and CALTRANS refer to PBPD as a design exception that requires decision rationale by the road design engineer. Two states indicated using an in-house tool for PBPD-related design decisions; Oregon DOT uses an Urban Design Concurrence (UDC) to document context determination and design decisions, while the Wisconsin DOT is equipped with a specific PBPD tool for pavement treatments and safety-driven geometric alterations. PBPD decisions are documented in technical reports, agency databases, PBPD toolkits, or design memos.

Table 4 – Please describe how PBPD decisions are approved at your agency (i.e., what does the approval path look like and who at the agency is involved)?

Agency/Department	What does the approval path look like?	Who at the agency is involved?	Others
Arizona DOT	Project team-> Technical team->Project manager-> FHWA (if necessary)	• State Engineers Office, • Infrastructure Delivery and Operations Division, • Transportation Systems Management and Operations Division (TSMO) • Multimodal Planning Division Senior Leadership Team are involved.	NA
Caltrans	Design PE-> Project development team Finally, decision is taken collectively.	• Design PE, • Project development team • Subject matter experts.	NA

Agency/Department	What does the approval path look like?	Who at the agency is involved?	Others
Colorado DOT	FHWA's approval is needed for PBPD decisions on NHS projects which may require supporting DDSA.	NA	NA
Connecticut DOT	None at this point.	None at this point.	NA
Florida DOT	District design engineer (unless the Florida Design Manual required Central Office approval)	• District Design Engineer	The context based design criteria are developed to incorporate PBPD decisions.
Illinois DOT	Personnel at Central Office-> FHWA (if applicable)	• Central office • District office are involved.	NA
Kansas DOT	Road design staff. The benefit-cost ratio is also considered.	• Road design staff	NA
KYTC/Division of Highway Design	Decisions are approved through design executive summary (DES) submittal process.	• Location engineer, • Central office roadway design branch manager, • Roadway design branch manager • Director of the Division of Highway Design	NA
Louisiana Department of Transportation & Development	PBPD decisions are approved as same as that of other design decision.	• Chief Engineer • FHWA	NA
Michigan DOT	Designers-> Project manager-> Engineer of road design-> FHWA (if applicable)	• Designers • Project manager • Engineer of road design.	NA
Minnesota DOT	District project manager (PM)->	• District project manager,	NA

Agency/Department	What does the approval path look like?	Who at the agency is involved?	Others
	Geometric design support Finally, district PM decides whether to accept or reject the recommendations by Geometric Design Support Unit. Final layout is signed by district engineer.	• Geometric design support unit, • State design engineer, • District engineer.	
Missouri DOT	Approved by core team	• Project manager and • Staff of other disciplines as well takes decision.	NA
New Hampshire	Chief project manager and Chief engineer (Design exceptions)	• Chief project manager • Chief engineer	No PBPD process yet
New York State DOT	Main office design quality assurance bureau (DQAB)	• Project developer and regional director	
North Carolina DOT	None at this point.	None at this point.	NA
Oregon DOT	The five Oregon DOT Regional Technical Centers-> central headquarters roadway unit (if needed)	• Technical staff and • Subject matter experts at central headquarters roadway unit and regional technical centers.	Urban Design Concurrence document is used. It brings planning activities and project development together.
Tennessee DOT	Based on project types and stage	• Strategic transportation investments division, • Regional project development offices, • Head quarter design division	Varies with project type/stage

Agency/Department	What does the approval path look like?	Who at the agency is involved?	Others
Texas DOT	Project requiring ROW are developed through schematic process that includes public meetings and hearings. Approved by district level or design engineer.	• District level design division. • For design exceptions district engineers are appointed.	NA
Utah DOT	Project manager and design team.	• Project manager, • Design/project team	NA
Virginia DOT	For all tier 1 and 2 projects: Preliminary engineering approval-> Right of way approval-> Construction approval	• Technical staff at central office, • District location and design engineer, • Project development engineer.	NA
Wisconsin DOT	Several certifications- pavement, safety, structure, operations, bike/ped are needed for decision making. Final approval is done by regional and central office.	• Regional project development chiefs (mainly involved) • Region local program manager • Local program section chief • Oversight engineer are also involved.	NA

Question 5. For which of these common project types does your agency apply PBPD or similar principles? (Check ALL that apply.)

Figure 11 indicates eight common project types (the ninth option as 'Other') that agencies apply PBPD or similar principles. The installation of low-cost safety countermeasures and selecting alternative designs to lessen cost were identified as the most common project type where PBPD is applied (both at 85.7 percent). However, the remaining agencies did indicate the use of AASHTO 2018 or following standard design practice. Illinois DOT reported using PBPD for projects on existing roads in accordance with the AASHTO 2018 guidelines. While North Carolina DOT, which indicates the use of standard design practice, reported that PBPD practice was not generally applied in any of the common projects listed. Eighty-one percent of the agencies applied PBPD for 'Obtaining design exceptions for lane and shoulder widths' and 'Using design exceptions or design variances to fulfill project objectives.' More than half of the agencies applied PBPD when modifying interchange designs, introducing active traffic management, and using alternative shoulder designs.

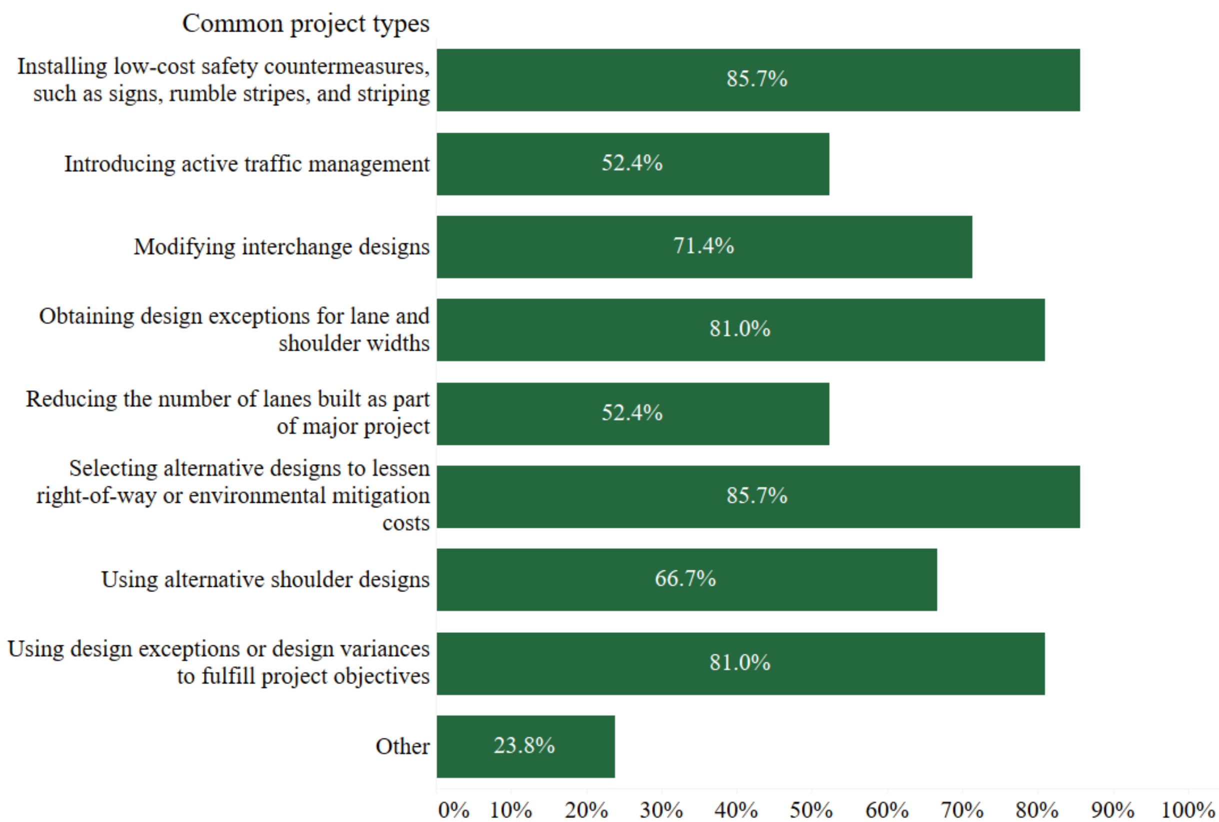

Figure 11 – For which of these common project types does your agency apply PBPD or similar principles? (Check ALL that apply.)

Question 6. When in the project process (e.g., planning, scoping, preliminary design, final design, construction) is the adjacent corridor or network considered? (Check ALL that apply.)

The stacked bar chart (Figure 12) shows the percentage that an adjacent corridor or network is considered (a five-point response; Always, Usually, Sometimes, Rarely, and Never) in five different project progress, i.e., planning, scoping, preliminary design, final design, and construction. Adjacent corridor or network is usually or always considered the majority of the time during the planning and scoping level of the project (84 percent). During the preliminary design, this drops to a total of 55 percent, though agencies reported that the adjacent facilities or network are sometimes considered at 25 percent of the time. However, in the project's construction phase, consideration for the adjoining corridor or network slightly increased (36 percent, always or usually) as compared to the final design (30 percent), which may reflect increased construction-related traffic management in the nearby roadway and network.

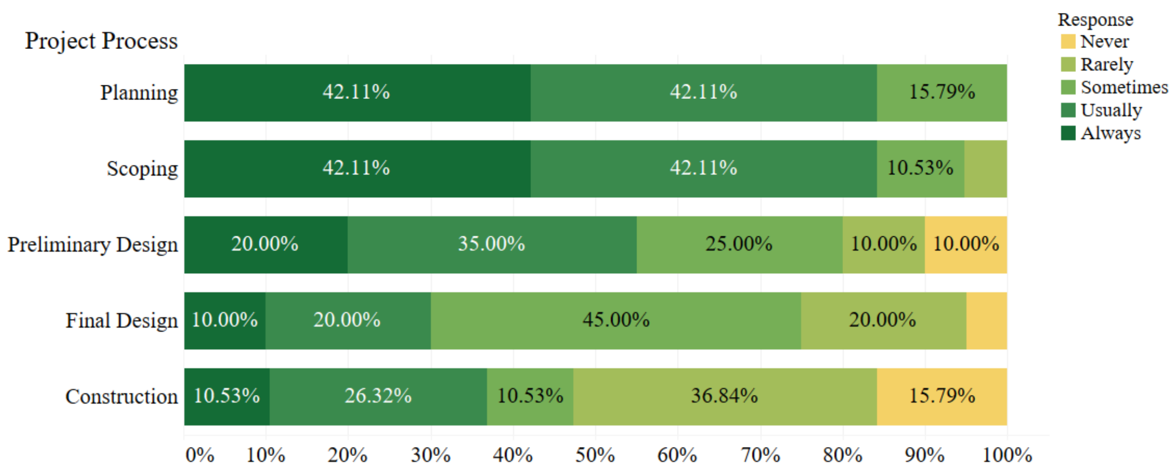

Figure 12 – When in the project process (e.g., planning, scoping, preliminary design, final design, construction) is the adjacent corridor or network considered? (Check ALL that apply.)

Question 7. How frequently does your agency utilize PBPD or similar practices at the following levels?

The percentage of PBPD utilization (a five-point response; Always, Usually, Sometimes, Rarely, and Never) for three different project levels; corridor-specific, project- or site-specific, and system-wide are displayed in Figure 13. Survey response indicates that PBPD utilization is more prominent at specific projects or sites than corridor or system-wide levels. The propensity of PBPD utilization reduces as the project scope increases, i.e., from corridor specific, to system wide. Agencies responses indicate that PBPD is utilized at the project- or site-specific level more than 60 percent of the time (48 percent Always, and 19 percent Usually). More than 30 percent of respondents stated that PBPD is rarely (9.5 percent) or never (28.6 percent) considered at a system-wide level.

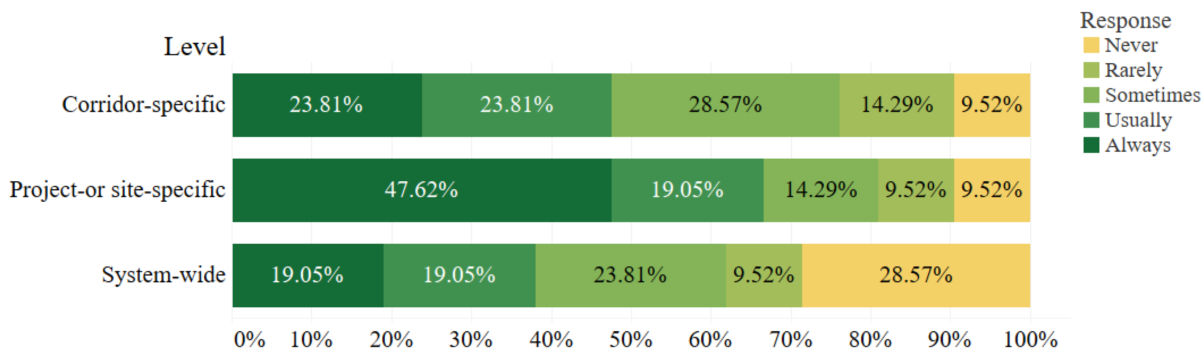

Figure 13 – How frequently does your agency utilize PBPD or similar practices at the following levels?

Question 8. What are your agency's existing guidelines or policies that describe how to define the purpose and need of improvement projects?

In response to the survey question of existing guidelines or policies describing how to define the purpose and need of improvement projects, most agencies are equipped with existing guidelines. Table 5 summarizes these guidelines name. Projects' purpose and needs were identified in the feasibility phase (Louisiana DOT), the preliminary design phase (Connecticut DOT), or before submission to the National Environmental Policy Act (NEPA) review process (Wisconsin DOT). Agencies like Minnesota DOT and Virginia DOT have separate documentation for project purpose and need. At the same time, some agencies reported on leveraging PBPD in their existing purpose and need guidelines such as Colorado, Illinois, and Arizona. Florida DOT indicated that projects' purpose and need are included in seven different manuals by the Florida DOT. Project need and scope have also been determined by regional plans such as the Transportation Improvement Plans in New Hampshire.

Table 5 – Agency's existing guidelines or policies that describe the purpose and need of improvement projects

Agency/Department	Guideline Name
Arizona DOT	Guiding Principles for Performance Based Practical Design
Caltrans	Caltrans Project Development Procedures Manual
Colorado DOT	Project Development Manual
Connecticut DOT	Project Development Manual
Florida DOT	Project Development and Environmental Manual
Illinois DOT	Needs assessment report; Effects of Asset Management and PBPD on Project Types / Policies; Illinois DOT Concept of how to apply PBPD for Projects on Existing Roads

Agency/Department	Guideline Name
Kansas DOT	Kansas DOT Bureau of Local Projects; Policy for non-freeway resurfacing, restoration and rehabilitation 3R projects
KYTC/Division of Highway Design	Overview of Performance Based Practical Design; Highway Design Manual
Louisiana DOT & Development	Stage 0 Manual of Standard Practice
Michigan DOT	MDOT Road Design Manual
Minnesota DOT	Purpose and need statement
Missouri DOT	Practical Design
New Hampshire DOT	Local Public Agency Manual for the Development of Projects
New York State DOT	Project Development Manual
North Carolina DOT	Project Management; Scoping Process NCDOT; NCDOT Roles and Responsibilities in Project Delivery
Oregon DOT	Blueprint for Urban Design ODOT's Approach for Design in Oregon Communities
Tennessee DOT	Multimodal Project Scoping Manual and Design; and Roadway Design Guidelines
Texas DOT	Project Development Process
Utah DOT	Practical Design Guide
Virginia DOT	Practical Design Flexibility in the Project Development Process
Wisconsin DOT	Project Management Plan Development

Question 9. To what extent does the determination of a project's purpose and need include a consideration of corridor and/or system needs beyond the boundaries of the project?

Agencies' responses varied on the extent of considering corridors or system needs beyond the project's boundaries within the project's purpose and need. On the one hand, similar to the response in Figure 13 (Question 7), some agencies reported that connecting facilities are seldom considered or are considered when sufficient funding is available (see Table 6). In Kentucky, the Division of Highway Design of the Kentucky Transportation Cabinet (KYTC) indicates that projects are usually part of long-term planning with predetermined start and end termini. Thus, projects rarely consider corridor or system needs beyond the boundaries of the long-term project plans. On the other hand, agencies indicate that connected corridor or systems needs are considered on a larger scale project. In addition, states such as Utah DOT, Kansas DOT, and Texas DOT reported that more minor projects, when included within longer-range plans, would also be designed for future needs, considering the compatibility of existing sections and future growth. Minnesota DOT, North Carolina DOT, and Arizona DOT indicate that the project development process considers adjacent corridors and affected networks due to project activities. When considering adjacent facilities and networks, agencies often quoted the connection or constraints related to pedestrians and bicyclists as factors. Illinois DOT is setting up the requirement for its districts to review needs beyond the projects termini to achieve a more holistic approach, specifically when accommodating or establishing facilities for pedestrians and bicyclists.

Table 6 – To what extent does the determination of a project's purpose and need include a consideration of corridor and/or system needs beyond the boundaries of the project

Agency/Department	Summary
Arizona DOT	Project prioritization during its planning and programming stage are evaluated. Corridor and system needs are evaluated prior to programming.
Caltrans	A planning document that details the ultimate development of the route/corridor looking towards a long-term horizon is used.
Colorado DOT	Varies
Connecticut DOT	This is considered at a very high level if project is part of a long-term corridor study or improvement.
Florida DOT	A great extent.
Illinois DOT	State DOT will be asking the districts to review the needs beyond the project termini to include major mileposts (intersection) to ensure a more holistic approach. This is especially relevant when trying to establish bike/ped accommodations.
Kansas DOT	Corridor limits would consider Average Annual Daily Traffic (AADT) ranges. If the AADT range changed greatly (say due to a cross street pulling off a lot of traffic) we would stop the corridor limits there.
KYTC/Division of Highway Design	Very rarely, since most projects are six year plan projects and the begin and end termini have already been determined as described with in the Highway Plan.
Louisiana Department of Transportation & Development	May be considered as part of the traffic study associated with a project's feasibility and/or environmental phase.
Michigan DOT	Does occur, but rarely. Generally, the thought process is just to bring everything up to current standards.
Minnesota DOT	MnDOT strides to prevent scope change after the planning and scoping phase (decided by planner and project manager), but in rare cases the limits of a project may change during preliminary design, and final design to account for new funding or an emergency need. The goal is to never change project limits during construction.
Missouri DOT	MoDOT Engineering Policy Guide (Category:126_Location_Study_and_Alternatives_Analysis) is used. Link provided.
New Hampshire DOT	A credible purpose and need must consider the context of a project in relation to its corridor and system to keep the project goals consistent with both prior and planned system improvements.
New York State DOT	During scoping and development of the purpose and need, the project corridor is studied to determine the full area of potential impact of a project, beyond the project limits. These include traffic impacts, diversions during construction, business impacts and effects of the project on corridor travel.
North Carolina DOT	In the development of Comprehensive Transportation Plans, problem statements are generated that feed directly into the Purpose and Need discussion for projects in a corridor. Documents/links provided.

Agency/Department	Summary
Oregon DOT	Region offices look at the corridor as a whole to establish system continuity for future projects. Some regions work proactively in advance of STIP project selection to establish goals at the corridor level prior to any project related scoping work. This helps define context and project parameters for the scoping teams.
Tennessee DOT	None
Texas DOT	Consideration of corridor/system needs is given in all Interstate and major highway corridor studies. Other routes warranting special consideration for corridor development include energy sector corridors (e.g. Permian Basin Corridor plan), evacuation routes, hazardous transport routing, military transport corridors, Texas Highway Freight Network (THFN = initiative for oversized truck routing, providing 18.5' bridge clearances), and TxDOT Bicycle Tourism Network.
Utah DOT	On larger capacity-type projects the corridor/system needs are absolutely considered. For smaller projects, future development plans along the corridors are considered while planning and designing the facilities to meet future needs.
Virginia DOT	Usually examines the operation of the corridor with respect to the individual project.
Wisconsin DOT	Does not currently take a corridor approach but we do take context into account when applying PBPD.

Question 10. If considerations beyond the boundaries of the project are included, how are changes made to the project after considering the adjacent network or how are the identified priorities of the corridor integrated into the project?

If considerations beyond the boundaries of the projects were included, agencies mainly reported that allocations to changes made to the project while considering adjacent networks are included in the project documentation within the project's purpose and needs, as shown in Table 7. This is identified in the earlier response, where connected corridors or systems are considered at the start of the project planning. Additionally, some agencies indicate that continuous project evaluation enables the team to address where changes in project scope may be identified (New Hampshire DOT, Oregon DOT). The North Carolina DOT includes considerations of system-wide impact within their Problem Statement development process. Additional documentation of changes may be included, such as the KYTC's Addendum, which is required to be approved by the undersigned of the initially approved delivery obligations. Texas DOT divided change requirements into various groups based on project cost; the Project Management Plans for major projects costing more than $500 million, the Initial Financial Plans for other major projects costing more than $100 million, and the Interstate Access Justification Reports, which address safety and operations. In Minnesota, its DOT reported that a process change is initiated when project scope changes due to new information about the adjacent network being discovered. The project manager investigates the benefits and impacts to the project scope, schedule, budget, resources, and the traveling public to determine if the work can be added or if it should be done as a separate project.

Table 7 – If considerations beyond the boundaries of the project are included, how are changes made to the project after considering the adjacent network or how are the identified priorities of the corridor integrated into the project?

Agency/Department	Summary
Arizona DOT	Project prioritization during its planning and programming stage are evaluated. Corridor and system needs are evaluated prior to programming. Results of these analyses are utilized when refining/defining a project's objectives and needs, along with prioritization.
Caltrans	Not responded.
Colorado DOT	Varies
Connecticut DOT	Another separate project would be generated.
Florida DOT	It depends.
Illinois DOT	It would be documented in the Phase I report as it is anytime outside factors are considered in a project.
Kansas DOT	Not sure.
KYTC/Division of Highway Design	An Addendum can be made and attached to current approved DES to explain and justify the changes. The Addendum would then have to be signed by all who signed the original DES.
Louisiana Department of Transportation & Development	Not responded
Michigan DOT	Not responded
Minnesota DOT	MnDOT has a scope change process. In which the project manager investigates the benefits and impacts to the project scope, schedule, budget, resources, and the traveling public to determine if the work can be added or if it should be done as a separate project.
Missouri DOT	Design and engineering determination regarding the independent utility of the section of roadway being considered and how driver expectation will find the solutions.
New Hampshire DOT	The project scope is continually evaluated, at least through preliminary design, to ensure it is consistent with the adjacent network.
New York State DOT	If potential adverse impacts are identified outside the established project limits, then mitigation measures are discussed within the scoping and/or design approval documents. Impacts which cannot be fully mitigated are explained and justified within those documents.
North Carolina DOT	Project's purpose and need are generated from the department's Comprehensive Transportation Plans (CTP) for the county or region. Therefore, considerations of system-wide impact are provided.
Oregon DOT	Goals and outcomes for a project are established through the ODOT Decision Framework.
Tennessee DOT	None at this point
Texas DOT	Initial financial and project management Plans are required for Major Projects (>$100M, and >$500M, respectively). Special corridors such as Interstate and major highway are prioritized.

Agency/Department	Summary
Utah DOT	While doing a major rehab or reconstruction of a roadway segment state DOT would generally design it for the future traffic needs. In some cases, DOT wouldn't overdesign the segment if it weren't realistic for the future traffic to reach that level.
Virginia DOT	Project priorities are usually identified early on in the scoping process.
Wisconsin DOT	Does not currently take a corridor approach but we do take context into account when applying PBPD.

Question 11. Which of these criteria does your agency typically consider in determining the purpose and need of improvement projects? (Check ALL that apply.)

Figure 14 indicates typical criteria considered in determining the purpose and need of improvement projects. Roadway performance-related criteria were generally identified by most of the agencies as required to determine the purpose and need of project improvements. All study agencies indicate operational performance (or level-of-service) and traffic safety as important criteria. Traffic congestion is considered a criterion by more than 85 percent of the agencies, and 71 to 76 percent of agencies considered system reliability, maintenance, life-cycle cost, freight movement (economic vitality), and accessibility as determining criteria. Environment sustainability and adjacent corridor or network need rank lowest as criteria used to determine the purpose and needs for project improvement, which only 57 percent of agencies consider.

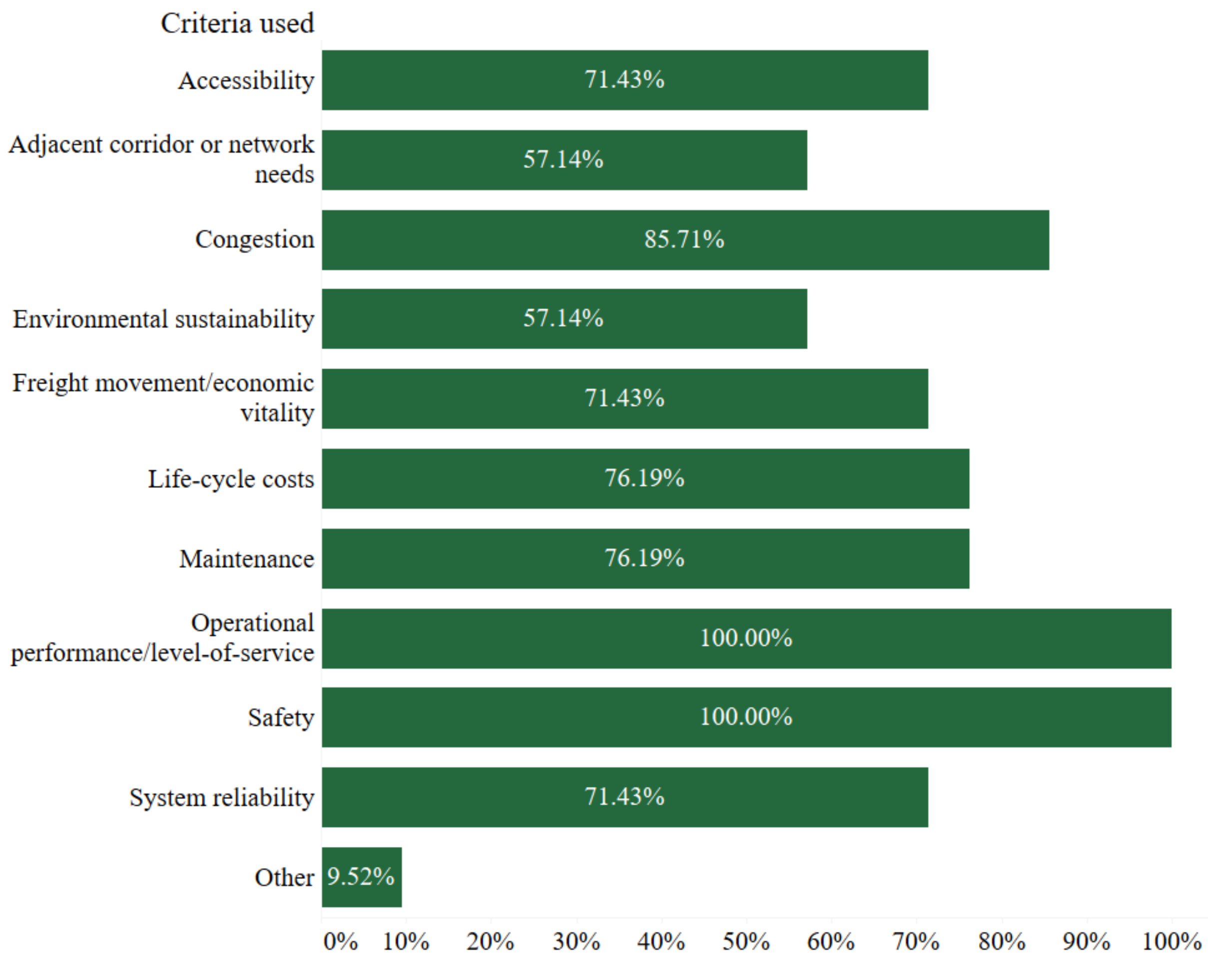

Figure 14 – Which of these criteria does your agency typically consider in determining the purpose and need of improvement projects? (Check ALL that apply.)

Question 12. What specific measures of effectiveness are used to quantify improvements across these criteria? (Please list criteria for each criterion from the preceding question.)

Each criterion considered in determining the purpose and need of improvement projects requires specific measures to quantify improvements. The following charts show percentages of effectiveness measurement for each of the ten criteria established in Figure 15. To note, Michigan DOT indicated that standard industry guidance was used across all ten criteria. At the same time, Colorado DOT reported that the effectiveness measurement varied project to project across all criteria.

A. Accessibility

Accessibility refers to the ability of various road users to reach desired services and activities. Figure 15 shows the percentage of measures of effectiveness for the accessibility criterion. Planning for accessibility is an emerging practice in transportation planning, although it has yet to be established in standard guidelines. Agencies surveyed listed one or more measures of effectiveness for accessibility. Agencies reported that effectiveness of accessibility measurement is project-specific or varies from one project to another. Some agencies also measured through ADA compliance, analysis of data from bicycle counters and applications, improvement in equity, referring to multimodal documents, standard industry guidance, as well as changes in traffic volume.

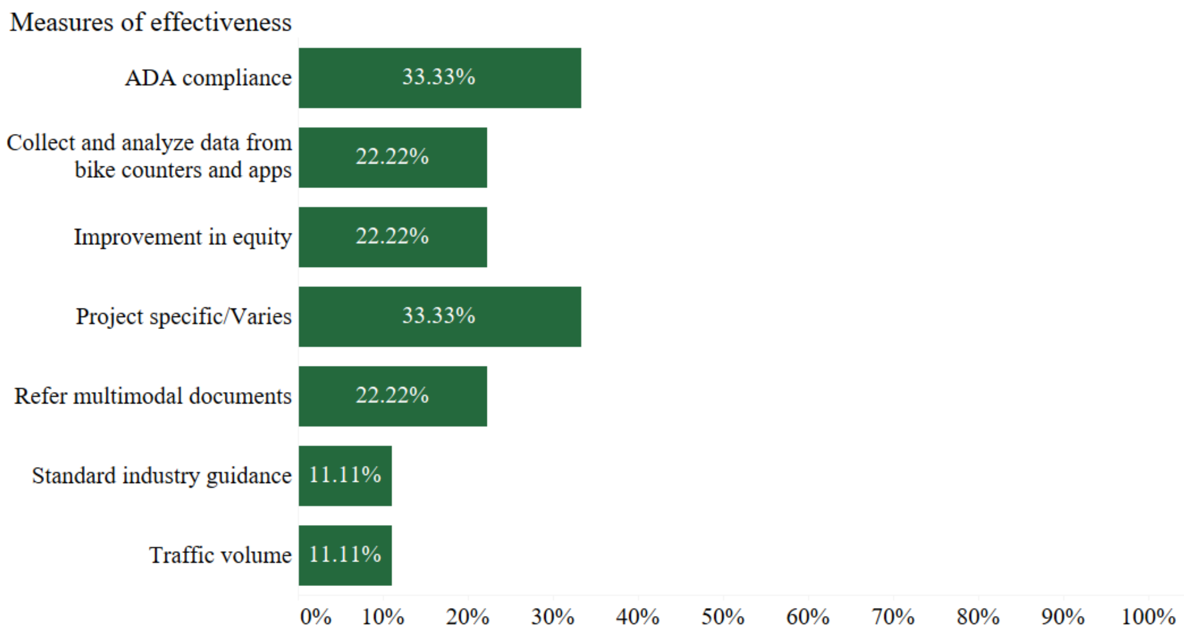

Figure 15 – Survey responses to accessibility measure.

B. Adjacent corridor or network needs

In measuring the effectiveness of considering adjacent corridor or network needs in the purpose and need of improvement projects, agencies indicate that the measurement varies by project. Additionally, agencies like MDOT use standard industry guidance to measure effectiveness. Figure 16 shows that two out of three agencies (Colorado DOT and North Carolina DOT) indicated a project-specific or varying approach to measuring the effectiveness of quantifying improvement in considering adjacent corridor or network needs.

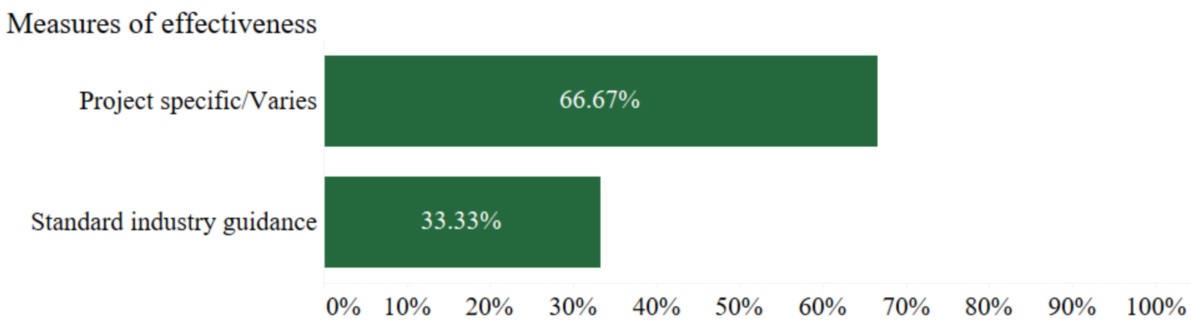

Figure 16 – Survey responses to adjacent corridor or network needs measures.

C. Congestion

In gauging the effectiveness of the congestion criteria, the Level of Service, travel time, and standard industry guidance make up the majority of the congestion effectiveness measurement. Other measurement methods for congestion criterion are through usage of the congestion index, congestion mitigation, and air quality, corridor simulation modelling technique, manuals, and standard industry guidance, as shown in Figure 17.

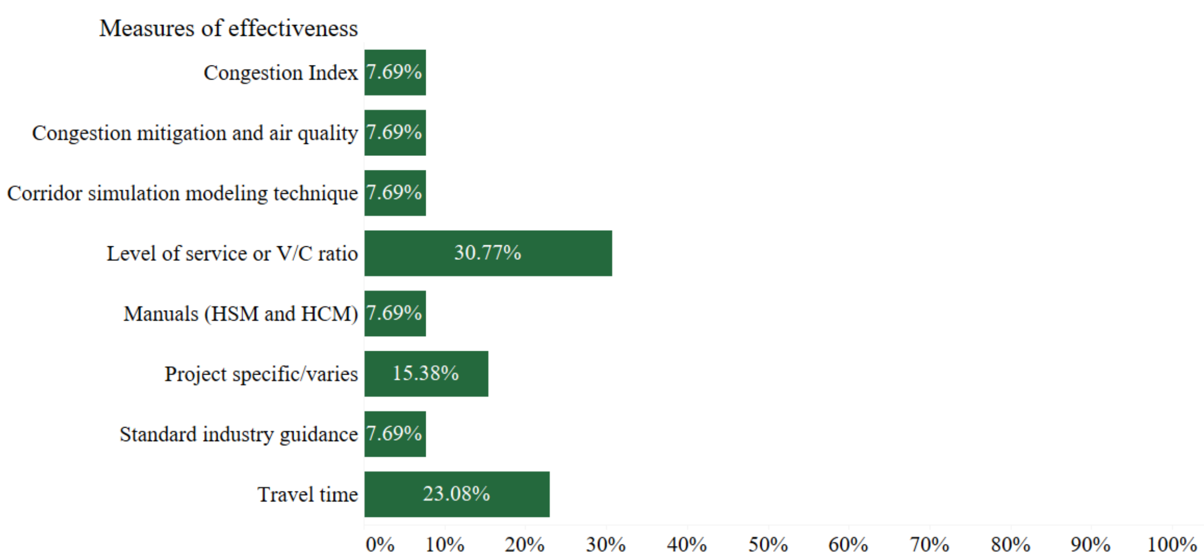

Figure 17 – Survey responses to congestion measure.

D. Environmental sustainability

Figure 18 shows seven types of measures of effectiveness for environmental sustainability in the purpose and need of improvement projects. Environmental impact assessment and reduction in green houses, climate change, or conserve resources make up the most (67% of respondents) preferred method used to measure environmental sustainability effectiveness. Additionally, about 22% of respondents indicated that they use multimodal inclusion as a measure of effectiveness within this criterion. Other methods include guidance from other divisions or programs, congestion mitigation, or previous historic, scenic and aesthetic project setting. It was also reported that the measures of effectiveness might vary from project to project.

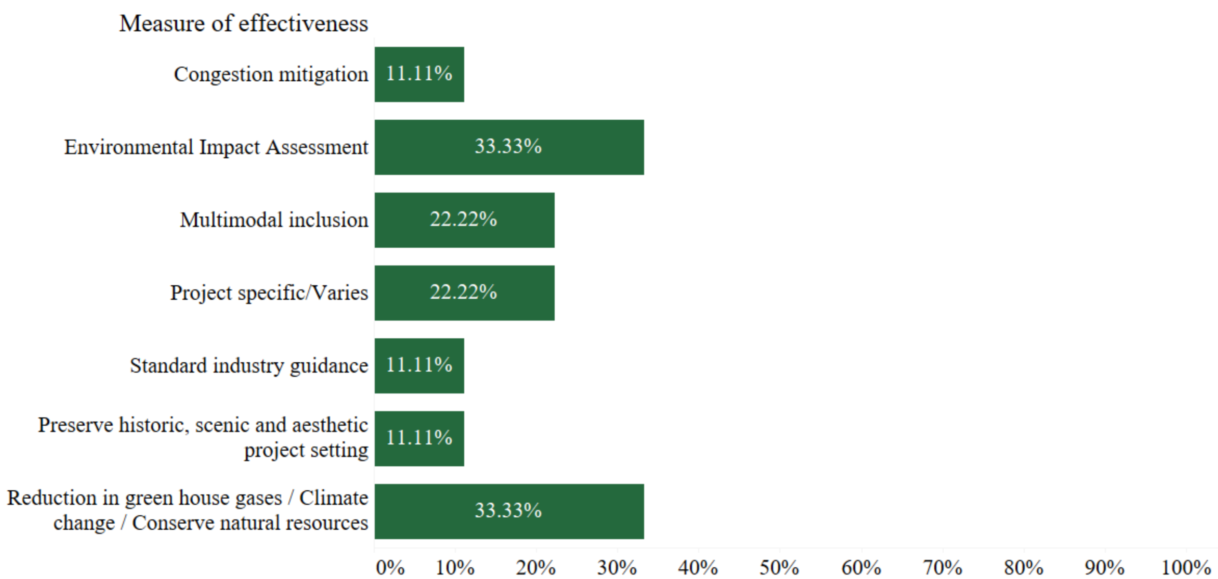

Figure 18 – Survey responses to environmental sustainability measure.

E. Freight movement/economic vitality

Figure 19 shows eight types of measures of effectiveness for freight movement or economic vitality in the purpose and need of improvement projects. Truck performance timing (delay and travel time reliability) makes up the most preferred method used to measure freight movement effectiveness. Additionally, accommodations made for trucks was also another method of measuring effectiveness within this criterion. Other methods include guidance from other divisions or programs, freight-related crashes, stakeholders' involvement, and standard industry guidelines. It was also reported that the measures of effectiveness might vary from project to project.

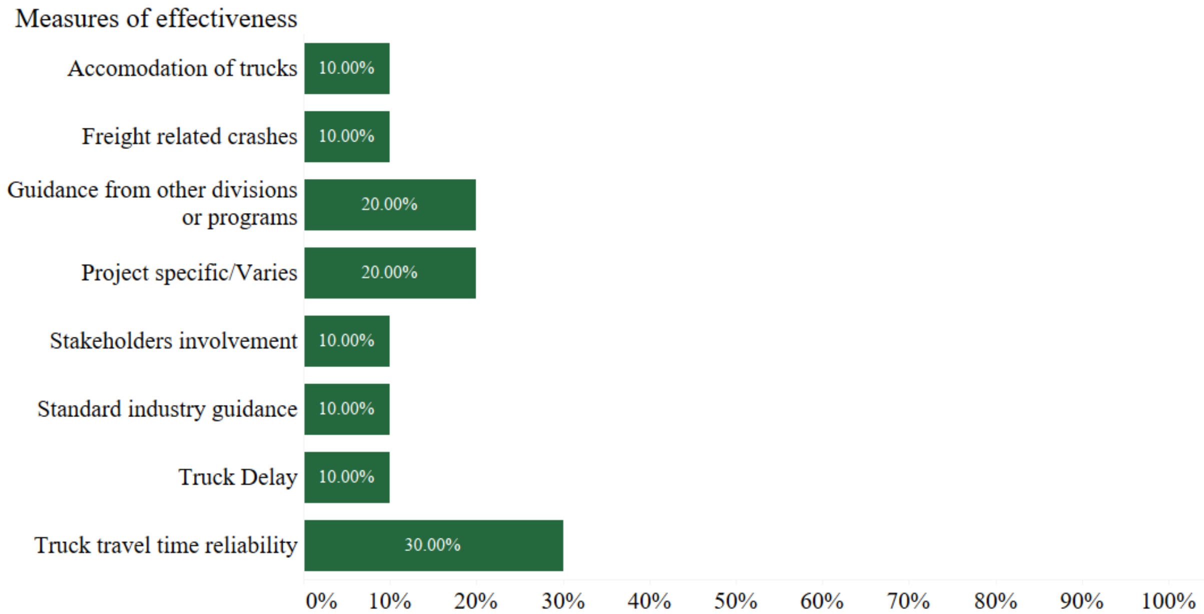

Figure 19 – Survey responses to Freight movement/economic vitality measure.

F. Life-cycle cost

When measuring the effectiveness of life-cycle cost in the purpose and need of improvement projects, Figure 20 shows that agencies chose to calculate the benefit-cost ratio or the cost of living as the top measurement of effectiveness within this criterion. This is followed by pavement design or pavement condition, intersection control evaluations, and standard industry practice.

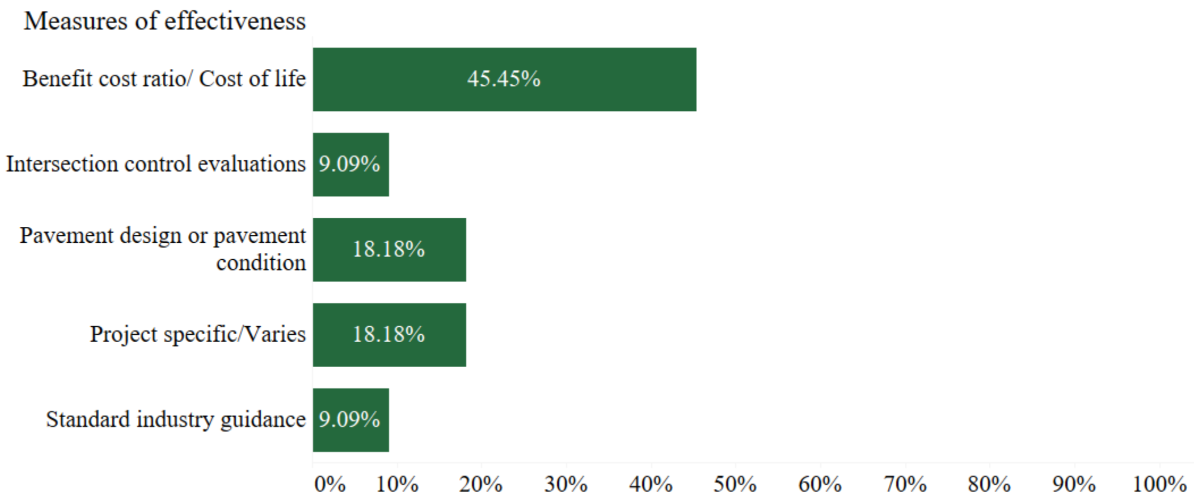

Figure 20 – Survey responses to life cycle cost measure.

G. Maintenance

Regarding maintenance, as shown in Figure 21, pavement ratings or maintenance ranked top among the method of measurement of effectiveness, both identified by Texas DOT. Other methods mentioned include reduction in maintenance, impact on service life, and long-term cost reduction.

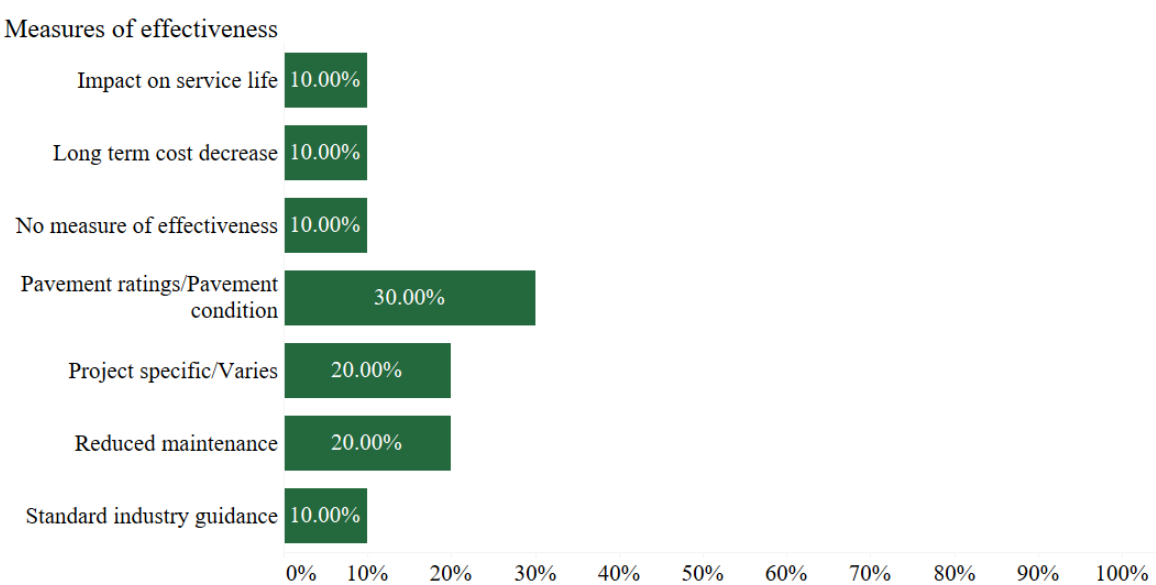

Figure 21 – Survey responses to maintenance measure.

H. Operational Performance

Figure 22 shows the method of measurement of effectiveness for operational performance. Agencies listed using Level of Service (LOS), or volume or capacity as the top measurement method for this criterion. Traffic operation-related indicators such as travel time, vehicle miles travelled, traffic delay, and traffic speed were also used as measures of effectiveness.

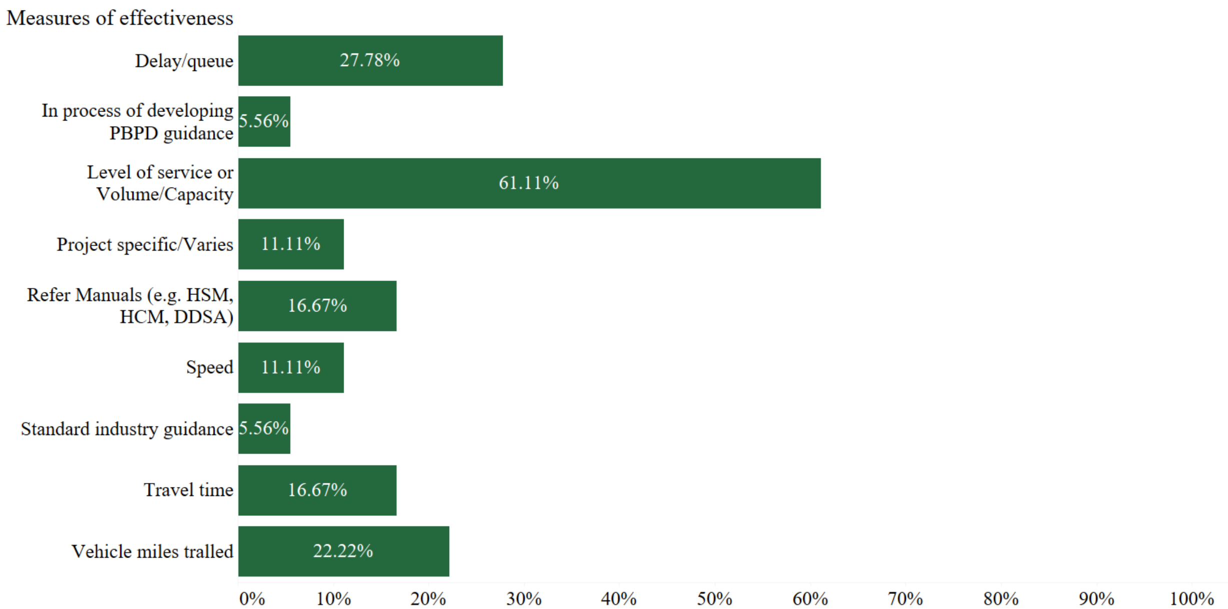

Figure 22 – Survey responses to operational performance measure.

I. Safety

The majority of the agencies identified crash-related indicators used as measures of effectiveness for the safety criterion. Agency-specific method was also listed; for example, Texas DOT developed a project safety scoring means for rural roads and Wisconsin DOT developed a Safety Certification Process (SCP) that adopted the Highway Safety Manual (HSM) analysis and economic appraisal method. Reference to manuals such as the HSM and the Data-Driven Safety Analysis (DDSA) were reported to be part of the measurement of effectiveness for the safety criterion, as shown in Figure 23.

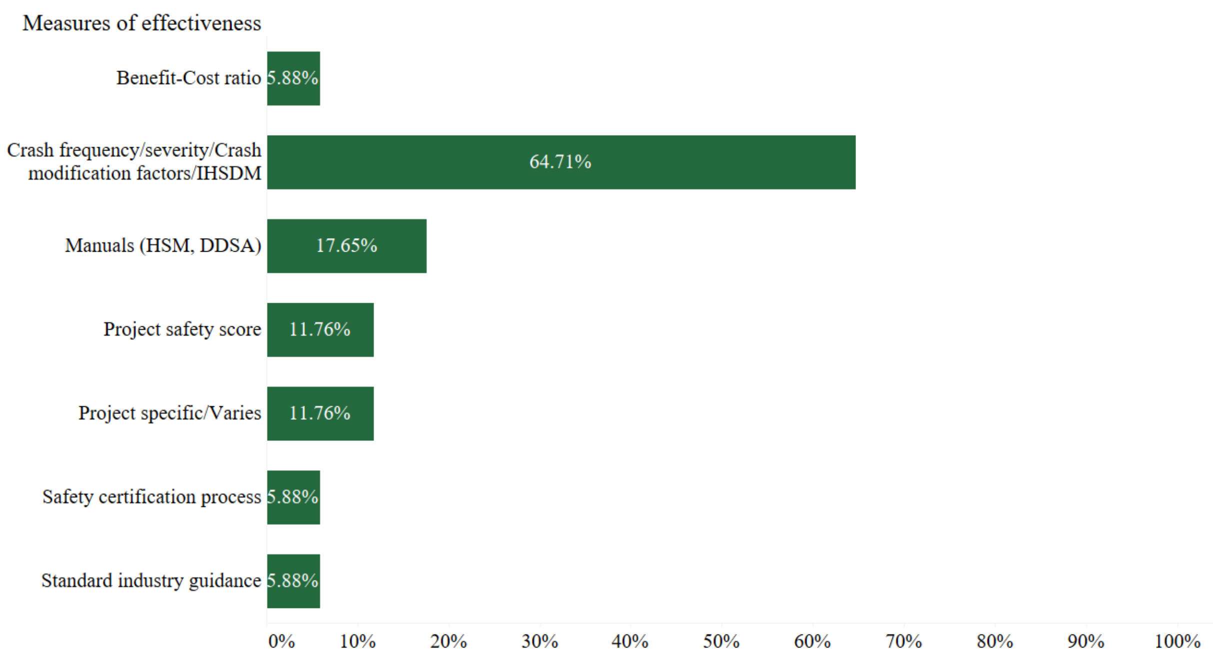

Figure 23 – Survey responses to safety measure.

J. System Reliability

System reliability is often related to travel time reliability, reflecting the quality and variability of travel time within a roadway system. Usually, system reliability is related to traffic operation, where consistency and predictability in travel time are considered a transportation system's reliability. This is reflected in agencies' response, where most agencies identified travel time as one of the effectiveness of system reliability measurements, as shown in Figure 24. Other measurements of the effectiveness of the system reliability criterion include; traffic speed, Level of Service, delay or queue, modelling of traffic simulation, as well as crash frequency or severity.

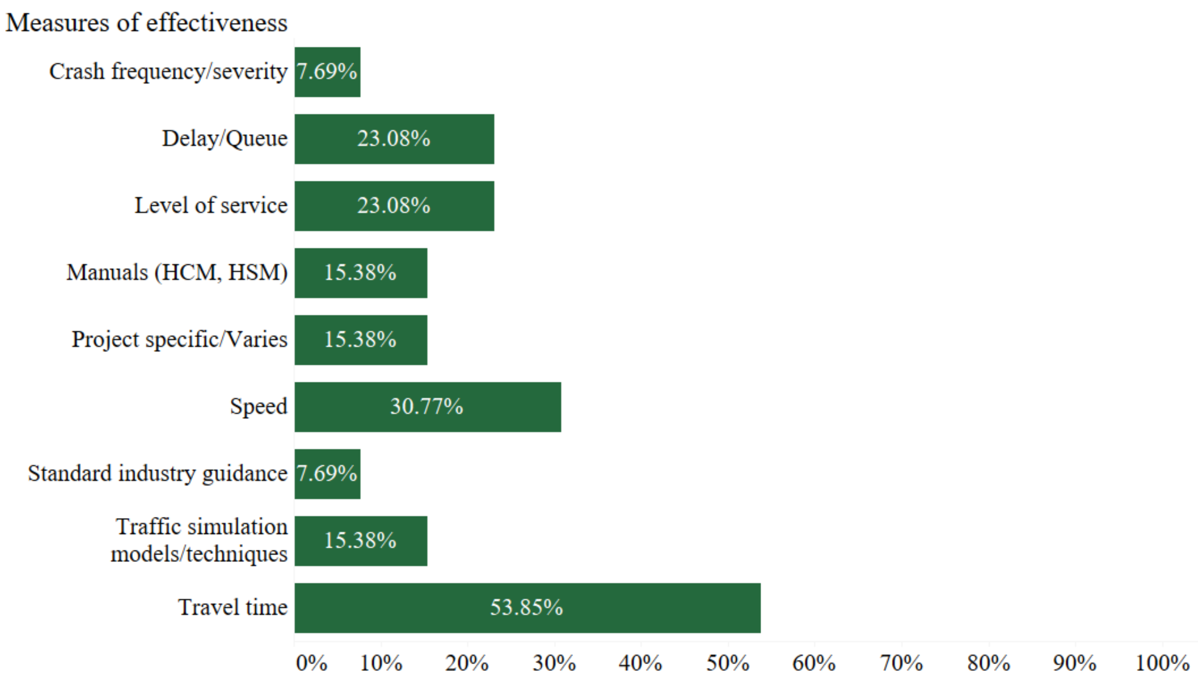

Figure 24 – Survey responses to system reliability measure.

Question 13. What evaluative methods does your agency use to determine whether the performance measures were met (e.g., whether the project was successful in accomplishing its purpose and meeting its need)?

Table 8 summarizes various performance measures reported by agencies to determine whether the project successfully accomplished its purposes and met its needs. Agencies such as Caltrans, North Carolina DOT, and Minnesota DOT indicated that the continuous evaluation throughout project implementation and addressing changes or issues that arise, leads to the finished product to meet its purpose. As an added element, Minnesota DOT also has a specific contract requiring two high-quality evaluations each year. Crash evaluation is conducted by various agencies as performance measures. Crash reduction analysis is conducted three years after the project completion by Tennessee; and KYTC for Highway Safety Improvement Program, HSIP projects. While Wisconsin DOT indicated that there is a requirement for a post-improvement safety evaluation for HSIP projects, normal project does not follow the same process. Wisconsin DOT, however, does have an effectiveness program that measures final pavement treatment along with the MAPSS (mobility, accountability, preservation, safety, and service) performance measures. Other agencies, which include crash analysis as performance measures, are Utah, Kansas, and New Hampshire. Additionally, the evaluation of level-of-service based on the Highway Capacity Manual (HCM) is also used to evaluate project performance (Louisiana, Kansas, and New Hampshire). Missouri listed public opinion surveys as performance measures of projects, while Connecticut reported the use of pre and post project data to evaluate project performance.

Table 8 – What evaluative methods does your agency use to determine whether the performance measures were met (e.g., whether the project was successful in accomplishing its purpose and meeting its need)?

Agency/Department	Summary
Arizona DOT	ADOT is currently developing these measurements/metrics as part of the development of it's PBPD Guidelines.
Caltrans	Most projects have well defined purpose and need hence they meet the goals.
Colorado DOT	It varies with projects.
Connecticut DOT	Data is gathered post project and compared to pre-project conditions.
Florida DOT	It depends on projects.
Illinois DOT	Do not measure after conditions.
Kansas DOT	Level of Service is measured through HCM. Safety is measured through HSM. Do not have specific performance measures on a project level but do check system wide effectiveness.
KYTC/Division of Highway Design	For HSIP projects before and after analysis is carried out by using 3 years of crash data, and then benefit-cost ratio is calculated. For non-HSIP no evaluation is done currently.
Louisiana Department of Transportation & Development	Use methods of Highway Capacity Manual and Highway Safety Manual
Michigan DOT	Unsure about any methods to evaluate post-construction.
Minnesota DOT	Check if the project purpose and need are met. Measures safety of the projects through specific contracts to monitor safety performance of specific countermeasure.
Missouri DOT	No specific measures. Selected projects have public surveys after project completion to measure the success.
New Hampshire	Operational: monitoring of traffic operations including LOS, delay, and queuing Safety: I before/after safety performance comparisons, usually done as part of HSIP annual reporting
New York State DOT	For safety needs, NYSDOT employs a formal Post-Implementation Evaluation System (PIES) to determine if safety goals were met. For infrastructure, NYSDOT uses pavement and bridge inspection scores. For congestion, NYSDOT reviews speed and travel time information from GIS-based systems.
North Carolina DOT	Through a merger process DOT work with other agencies on permitting aspects of major projects and check performance.
Oregon DOT	To be determined later.

Agency/Department	Summary
Tennessee DOT	3 years after project completion the Safety Office reviews to confirm if crash rates have been reduced.
Texas DOT	None at this point
Utah DOT	Improvements in congestion is observed in short term after opening new facility. Crash reduction is observed on a longer term. Life cycle cost are observed on a system basis.
Virginia DOT	Not responded
Wisconsin DOT	No evaluation method currently. HSIP projects have post improvement safety evaluation, but normal projects do not have same process.

Question 14. Which of these analytical tools does your agency use as a part of its planning and design practices? (Check ALL that apply.)

Various roadway planning and design tools such as guidelines (AASHTO Green Book, Highway Safety Manual, or Highway Capacity Manual) and simulation software can assist road engineers. The survey indicates that transportation agencies make full use of agency-specific design guidelines and traffic simulation software (e.g., VISSIM, Synchro, Dynasmart-P, SIDRA, and others) as part of their planning and design practices. The majority of the agencies also include using the AASHTO Green Book (95 percent) and the Highway Capacity Manual (95 percent). Additionally, evaluation models such as the Interactive Highway Safety Design Model (IHSDM) (which includes five evaluation models, i.e., Crash Prediction, Design Consistency, Policy Review, Traffic Analysis, and Driver/Vehicle and an Economic Analyses Tool) used by 71 percent of the agencies. Oregon DOT also reported using the CMF Clearinghouse as an evaluation tool. The crash modification factor (CMF), a multiplicative factor, computes the expected number of crashes after a countermeasure is implemented at a specific site. Lesser used tools were Safety Analyst and the NACTO Urban Street Design Guide, used only by 43 percent and 38 percent of the agencies, respectively. Agencies recorded other design guides related to street design, such as the AASHTO Bike Guide and the Public Rights of Way Accessibility Guide, as shown in Figure 25.

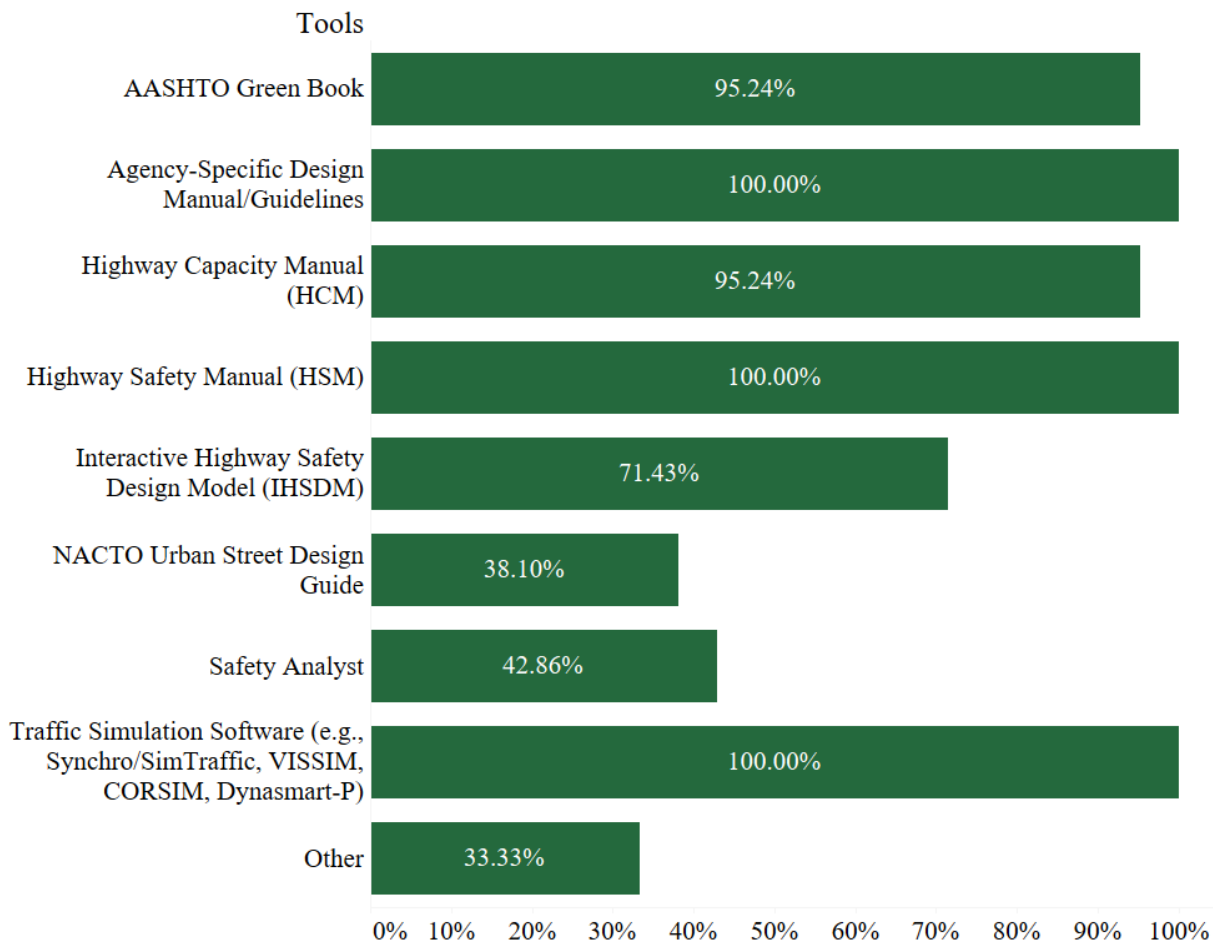

Figure 25 - Which of these analytical tools does your agency use as a part of its planning and design practices? (Check ALL that apply.)

Question 15. Does your agency employ any of the following practices to help ensure successful implementation of PBPD or similar philosophies? (Check ALL that apply.)

PBPD or similar philosophies depend on various aspects for its successful implementation, from revising existing policies to having a PBPD champion leading implementation at all levels of an agency. The survey indicated that PBPD principles are generally observed at an implementation and policy revision level. More than 75 percent of agencies reported that engineers are encouraged and empowered to exercise judgments on projects based on PBPD principles. In addition, 62 percent of agencies indicated policy and guideline revision to include PBPD values to facilitate a multi-disciplinary comprehensive approach to delivering projects under PBPD. Outside of the agency policy and guidelines, only 47 percent of agencies indicate engaging activities with the FHWA division during PBPD implementation. There also seems to be less support among the executive levels within agencies (47 percent) which may contribute to difficulty in communicating support to all state employees and consultants. Another big gap revealed by the survey is the lack of a champion leading the implementation of PBPD throughout all levels of the agency. Only 19 percent of the agencies indicated that personnel leads PBPD coordination at all levels within an agency, as shown in Figure 30

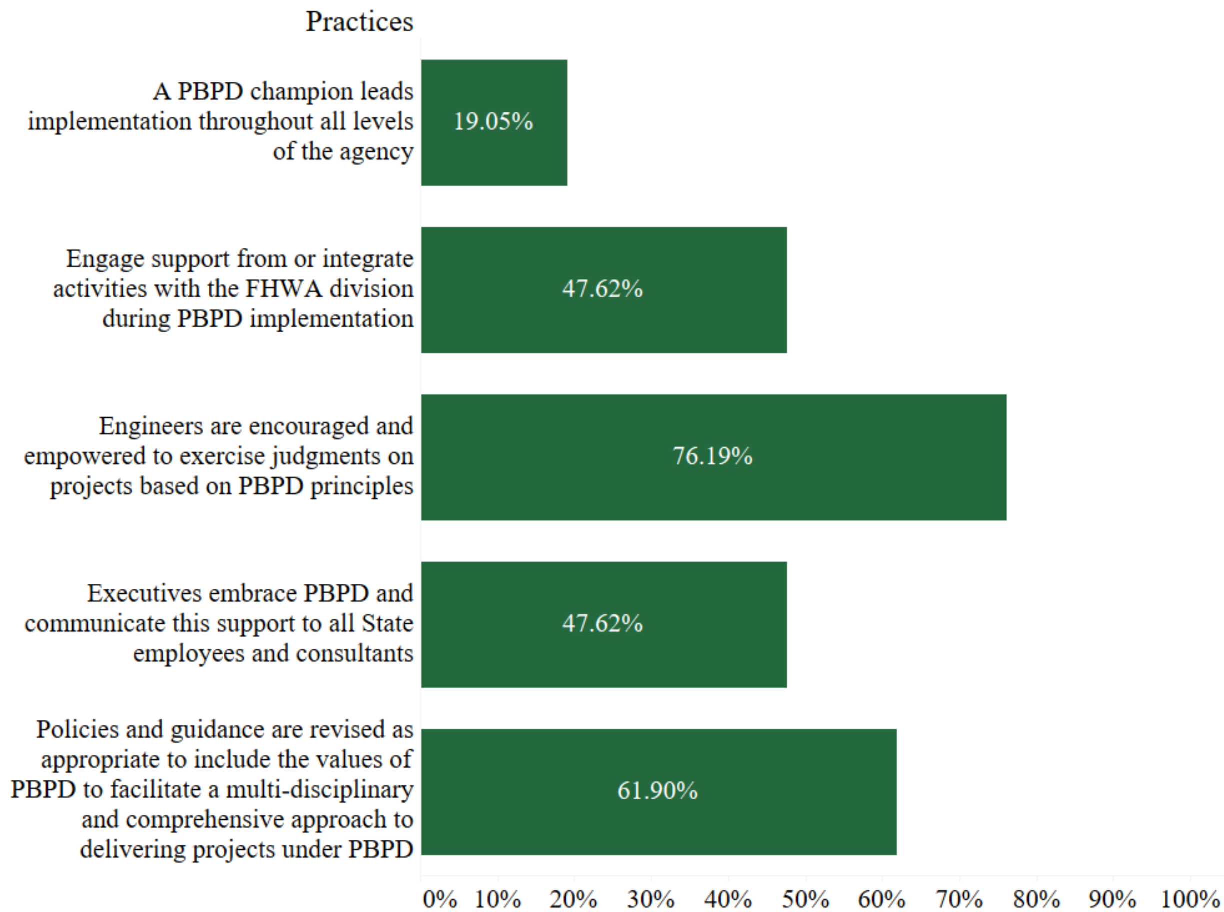

Figure 26 - Does your agency employ any of the following practices to help ensure successful implementation of PBPD or similar philosophies? (Check ALL that apply.)

Question 16. Please provide details of any revisions or changes to existing practices that would be necessary or helpful to produce improve your aency's abilities to implement a PBPD approach?

As States adopt practical design and strategies, revisions or changes are made to existing procedures in agencies to facilitate PBPD using various analytical tools. Currently, Minnesota DOT and Virginia DOT indicate active use of PBPD decisions in projects. MnDOT also reported documenting all the PBPD decisions made within projects using a PBPD documentation template in various existing design documents. Additionally, MnDOT, along with Colorado DOT and Oregon DOT, are in the process of updating guidelines and manuals, integrating PBPD into appropriate sections, while Arizona DOT is developing a specific PBPD guideline.

The Louisiana DOT and Utah DOT identified the use of the AASHTO Green Book Version 7 to incorporate PBPD in the planning and design. Utah DOT, however, pointed out that developing specific minimum standards for different context types would be helpful for PBPD applications. The California DOT included quantifiable pedestrian and bicycle PBPD strategies for roadway segment and intersection, and quantifiable safety tools not covered in the HSM, e.g., managed lanes (high occupancy, congestion priced, or exclusive lane use), high volume routes with more than ten lanes, and some ramp terminal configurations.

Some agencies reported that their existing procedures included practical design, and thus no changes have been made regarding improving PBPD implementation. Missouri DOT highlights roadway safety; communication between stakeholders, designers, and administration office; and quality within their existing design process. At the same time, the existing Florida DOT manuals which also did not indicate any additional changes for PBPD implementation, did include suggesting safety for all road users; invest in existing and emerging communities; promote all modes of transportation; transportation solution must support context of area. Similarly, Kansas DOT highlights a clear understanding of roadway context, scope and location of project, public engagement etc., all necessary for PBPD implementation. Connecticut DOT focused on the need for better communication to provide educational components in assisting the establishment of the PBPD approach.

As pointed earlier, a PBPD champion is essential in aiding implementation through all levels within an agency. Thus, Michigan DOT moves to establish a figure to spearhead PBPD approaches, providing synergy across multiple areas within the department. Other changes that agencies have done to assist PBPD implementation include improving location-based evaluation. Wisconsin DOT developed an operation-based certification to screen locations with operational needs, while KYTC incorporated Intersection Control Evaluation to assist intersection evaluation and implement the PBPD approach. The summary of these revisions is highlighted in Table 9.

Table 9 - Please provide details of any revisions or changes to existing practices that would be necessary or helpful to produce improve your agency's abilities to implement a PBPD approach?

Agency/Department	Summary
Arizona DOT	Currently developing PBPD guidelines.
Caltrans	Quantifiable pedestrian and bicycle PBPD strategies for roadway segments and intersections. Quantifiable safety tools for HOV/HOT/Managed lanes, high volume routes with more than 10 lanes, and other ramp terminal configurations not covered in the HSM. PBPD tools specifically for geometric design.
Colorado DOT	Incorporating PBPD content into new design guidebooks.
Connecticut DOT	A robust educational component would need to occur prior to establishing guidance and practices for a PBPD approach.
Florida DOT	The manuals suggest- safety for all road users; invest in existing and emerging communities; promote all modes of transportation; transportation solution must support context of area (extracted from document)
Illinois DOT	Incorporating flexible design approach and multidisciplinary approach (extracted from document) Stakeholder involvement (extracted from document)
Kansas DOT	Clear understanding of roadway context, scope and location of project, public engagement etc. are necessary for PBPD implementation (extracted from document)
KYTC/Division of Highway Design	Incorporate intersection control evaluation (ICE) to help evaluate intersections across the state and implement the PBPD approach.

Agency/Department	Summary
Louisiana DOT & Development	Green Book 7 has provided sufficient guidance.
Michigan DOT	A champion to spearhead these approaches and provide some synergy across multiple areas in the department.
Minnesota DOT	Document all the PBPD decisions made in the project. Develop one single design manual that has all PBPD information.
Missouri DOT	Practical Design has been part of design process since the early 2000's.
New Hampshire	PBPD has not yet been adopted.
New York State DOT	Improvement in NYSDOT community outreach would result in better implementation of Context Sensitive Design techniques.
North Carolina DOT	No official policy on PBPD. Piloting into the process would likely be a first step.
Oregon DOT	In the process of updating our highway design manual and incorporating the concepts of PBPD and revised context based urban design criteria into it.
Tennessee DOT	No information provided
Texas DOT	No changes proposed.
Utah DOT	Recently adopted the 7th edition of AASHTO Green Book. Development of different minimum standards for each context type would be helpful for PBPD.
Virginia DOT	PBPD is an existing project development and design approach in use at VDOT
Wisconsin DOT	Develop operation-based certification (like the safety certification) to screen locations with operational needs.

Question 17. If your agency has developed any tools or software to assist with integrating PBPD principles into your design process, please provide a brief explanation and details of these tools below. If possible, please provide a copy of these tools by email to pete@msu.edu or upload them at the end of this survey.

Additionally, agencies have also developed in-house tools to assist in PBPD implementation. Table 10 shows various agencies' tools to assist with integrating PBPD principles into the design process.

Table 10 - If your agency has developed any tools or software to assist with integrating PBPD principles into your design process, please provide a brief explanation and details of these tools.

Agency/Department	Response Summary
Arizona DOT	None at this point.
Caltrans	Caltrans HSM Screening Tool - Helps to screen which projects are eligible to utilize the HSM for an alternative analysis or to analyze the safety impacts of a nonstandard feature. Caltrans Collision Cost Estimating Tool - this tool converts a project's HSM predicted collision output to California collision dollars.
Colorado DOT	Use software developed by others.
Connecticut DOT	None at this point.
Florida DOT	▪ PBPD process uses appropriate performance analysis tool and considers both short- and long-term planning. ▪ Partnered with FHWA in creating- Community Impact Assessment: A Quick Reference for Transportation, 2018 Update. ▪ This document suggests a variety of tools and techniques: Statistical analysis, comparisons, mapping overlays, public meetings etc.
Illinois DOT	▪ No tool/software developed by agency. ▪ But would like to use the spreadsheet tool developed as a part of NCHRP 15-50. This uses predictive modeling of the HSM and cost data to generate different options of geometric improvements that can be made and their relative B/C ratios.
Kansas DOT	▪ Developed tools based on 3R guidance. Shared rural multilane and rural two-lane tool with MSU (excel sheet). These tools take a variety of inputs like lane width, shoulder width, vertical curve presence etc. (extracted information from tools).
KYTC/Division of Highway Design	▪ Use Crash Data Analysis Tool and develop CMF spreadsheet. ▪ KY's HSIP encourages project designers to create an excel spreadsheet for HSIP corridor projects. The rows of the spreadsheet represent historical crashes and columns include crash data fields and roadway attributes.
Louisiana DOT & Development	No information provided
Michigan DOT	No information provided

Agency/Department	Response Summary
Minnesota DOT	▪ No information provided but have a formal PBPD process. ▪ Highway Safety Manual and Interactive Highway Safety Design Model are used frequently.
Missouri DOT	No information on tools. But indicates that tools are integrated into policies and specifications. In general use traffic modeling software to analyze traffic and select proper design.
New Hampshire	None at this point
New York State DOT	No automated tools or software have been developed.
North Carolina DOT	Not applicable
Oregon DOT	Indicates Highway Safety Manual and Highway Design Manual and Traffic Manual are generally referred. Provided link to a document
Tennessee DOT	Multimodal priority tool
Texas DOT	▪ Use Safety Score Tool developed by Texas A&M (TTI Office) and is used to evaluate rural two-lane and multi-lane alternative designs and provide an MOE for each alternative. ▪ Use Texas Congestion Index, Truck Reliability Index, Freight Investment Optimization Tool, Truck Congestion Analysis Tool, Texas Freight Investment Plan Tracker.
Utah DOT	No information provided
Virginia DOT	▪ Does not have any tools or software to integrate PBPD into design. It is a mindset at the agency that is inherent in all designers. ▪ Agency looks for flexibility in all design as provided for in the Greenbook and the VDOT Road Design Manual.
Wisconsin DOT	Own version of the Highway Safety Analysis Benefit-Cost Tool that is used only when Interactive Highway Safety Design Model is not applicable.

Question 18. If your agency has any guidance documents that have been developed, or are used, in support of PBPD or similar programs, please email or upload them at the end of this survey.

Figure 27 shows that approximately 72% of respondents either emailed, provided a link, or uploaded a guidance document that is related to PBPD or similar activities at the end of the survey in response to question 18 from the survey.

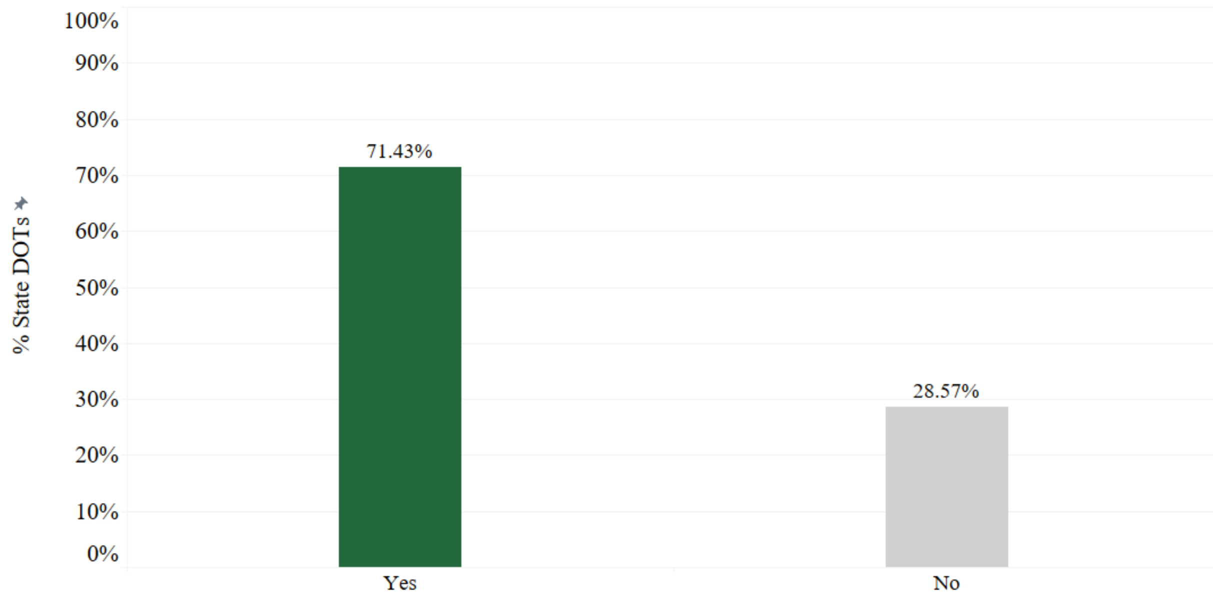

Figure 27 - If your agency has any guidance documents that have been developed, or are used, in support of PBPD or similar programs, please email or upload them at the end of this survey.

Question 19. If there is any additional information you believe is pertinent to your agency's PBPD or similar activities that has not been captured previously, please provide details here.

Finally, four state DOTs provided additional information at the end of the survey when they were asked to add any activities pertinent to PBPD that were not captured previously in the survey, as shown in Table 11.

Table 11 - If there is any additional information you believe is pertinent to your agency's PBPD or similar activities that has not been captured previously, please provide details about that.

Agency/Department	Response Summary
Arizona DOT	FHWA included a Safety Improvement Evaluation from Arizona as part of its case studies on PBPD published on: https://www.fhwa.dot.gov/design/pbpd/case_studies.cfm
Florida DOT	Interested to participate in teleconference, or virtual meetings if necessary.
Kansas DOT	Moving slowly towards PBPD
Oregon DOT	Incorporates PBPD at every level of design process and expects 8th edition of Green Book will have more information on PBPD.

5. PBPD In MDOT Business Units

Based on the findings from the literature review and survey of other states, the research advisory panel identified four areas within MDOT where PBPD principles may best be implemented. Discussions with each service area were conducted to see the ability for which PBPD could be implemented or if there were aspects already in place. Design exceptions were raised multiple times and therefore these were reviewed in greater detail in Section 7.

5.1. Safety

Safety analysis within MDOT has long utilized performance as a metric, from simple analyses of changes in crashes, to a normalized estimate of benefit-cost utilizing the Time-of-Return (TOR) spreadsheet, to more robust predictive analyses utilizing the Highway Safety Manual (HSM) including high-quality crash modification factors (CMF), safety performance functions (SPF), and Empirical Bayes to mesh historical (observed) crashes with predictive models to estimate a change in safety performance. These changes in safety performance may be converted to a potential safety benefit (or disbenefit) based on crash costs provided by various sources including the HSM, the National Safety Council (NSC), and updated based on yearly factors.

"Performance-Based" is analogous to "Data Driven", and Data Driven Safety Analysis (DDSA) has long been a requirement. MDOT's Safety Programs Unit generated a draft document regarding PBPD which had been circulated to MDOT's Executive Operations Committee (EOC), and this current research project is partly in response to that document. This is from a desire to move beyond just DDSA and implement performance-based thinking into other areas of MDOT. The draft PBPD document was put together to initially help local FHWA and other MDOT staff gain a better understanding of PBPD and begin investigating a uniform way for staff to implement PBPD across the entire network.

Some outcomes from the EOC review included North Region adding a year to their scoping process to better consider PBPD elements. Other ways that the Safety Programs Unit has furthered PBPD is by broadly promoting the use of tools and associated trainings such as the Highway Safety Manual. MDOT has developed state-specific SPFs that include additional facilities beyond the original HSM. There have also been discussions about further development of new SPFs, such as for limited-access facilities (e.g. freeways), but the reinvestment may not be worth the effort; for example, there may not be enough locations to develop an SPF or CMF for certain improvements on freeways.

It was also noted that there have been instances where PBPD principles have already been implemented in Michigan. In particular, there have been analyses of shoulder widths (such as the I-75/I-69 interchange and in University Region) where CMFs for shoulder widths have been used to optimize proposed designs.

At the time of this discussion there was not institutional knowledge that other states were leading the way in PBPD. One area highlighted though was Utah, where part of the scoping process requires documented what the goal or purpose of a project is; if MDOT adopted this then following up after the project should be required to see if the ultimate design met the proposed goals. In January 2021, a draft guidance document regarding Performance Based Practical Design was developed (see Appendix B) though not finalized pending the outcome of this research project.

5.2. Operations

MDOT's Congestion and Reliability Unit requires data-driven analyses for their operations template. This includes modelling of various scenarios and benefit cost analyses when selecting a project. Ultimately, a proposed project needs to demonstrate that it will meet project goals which may relate to capacity, throughput, delay, or other metrics. This utilizes the Operations Benefit Cost Spreadsheet which is available from MDOT; this requires inputs including proposed construction costs, a traffic analysis (using Synchro, Highway Capacity Software, RODEL, or SimTraffic), and safety benefits. To better standardize some processes, the Congestion and Reliability Unit initiated a research project for the development of a Michigan-specific protocol manual for VISSIM modelling, which provides clear procedures for both contractors and MDOT staff.

5.3. Pavements

MDOT has a process to consider whether a Portland Cement Concrete (PCC) or Hot Mix Asphalt (HMA) pavement would best match the desired lifecycle of a project; this lifecycle cost analysis (LCCA) is mandated for projects. In discussions with MDOT's pavement engineer it was noted that this process is codified and not readily modified so the decision to utilize a PCC or HMA pavement is not easily adapted to additional performance-based considerations, though long-term performance data from past pavement projects has guided this process as similar pavement designs can be compared against the body of knowledge from existing projects.

5.4. Maintenance

MDOT initiated a performance-based maintenance (PBM) program, to better guide investments based on system need within a fiscally constrained environment. This effort referenced local and international experience in the implementation of performance-based contracting for outsourced highway models and applied them to maintenance delivered by internal MDOT forces and other agencies. The initial goals of this program included at least a 5% cost/efficiency savings, improved performance in asset inventory and data management practices, improved speed of identification and adoption of innovations, that Level of Service (LOS) could be understood and managed, and consistent performance levels and outcomes across the network.

Performance measures were based on ensuring network functionality (i.e., at what level does a deficiency need to be corrected) and were monitored via a sampling program that selected random segments of the network state-wide. These were grouped into roadway, traffic safety services, and roadside categories. The results could be rolled up to the county, TSC, region, and ultimately state-wide level to indicate system performance. These measures were detailed in a handbook and training was presented to staff in each region. The network was monitored for multiple years and then targets were set based on the long-term average.

One notable outcome was from a pilot initiated by MDOT's Southwest Region. They wanted to improve their performance in shoulder safety as they recognized that there was a safety concern when gravel shoulders were not properly graded as edge drops could snag a vehicle tire increasing the risk of a run-off-road crash and poor drainage could further accelerate the deterioration of the gravel shoulders. They invested additional maintenance dollars in additional shoulder maintenance in 2015 and saw their regional shoulder performance measures score increase by more than 30%.

While parts of the program have been continued, funding continues to be challenging and MDOT has not easily been able to additionally modify the maintenance program to be fully performance-based based.

5.5. Summary

The concept of basing decisions on data and past performance is ingrained at MDOT. The title "Performance-Based Practical Design" may not have been applied though performance has historically – and continues – to drive many design and maintenance decisions throughout the department. The earlier in a project's lifecycle that PBPD is implemented the greater the opportunity to narrow the scope to only the areas that relate to the documented purpose and need. This in turn requires greater detail in documenting the basis of design, including documenting which standards were in place at the time.

6. Tools and Procedures

Multiple data sources, tools, and procedures may help practitioners implement PBPD. These may be used as inputs (data) or ways of comparing alternative and understanding potential impacts. Additional sources may be developed, and existing sources may be sunset at any time.

FHWA Office of Safety

https://safety.fhwa.dot.gov/

Resources for multiple program areas including HSIP, Intersection Safety, Guardrail Resources & ISPE, Roadway Departure Safety, Roadway Safety Data & Analysis, Pedestrian & Bicycle Safety, Local and Rural Road Safety, and Professional Capacity Building

NHTSA Crash Data and Safety Facts

https://cdan.nhtsa.gov/stsi.htm

The National Highway Traffic Safety Administration (NHTSA) is an agency of the United States Department of Transportation that conducts research and develops regulations for motor vehicle and highway safety. NHTSA provides summary statistics for each state regarding traffic fatalities, rates, and vulnerable road users.

NHTSA Fatality Analysis and Reporting System

https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars

The Fatality Analysis Reporting System (FARS) is a nationwide census providing NHTSA, Congress and the American public yearly data regarding fatal injuries suffered in motor vehicle traffic crashes. FARS collects data on all fatal crashes that occur on public roads and highways in the United States, including those involving motorcyclists, pedestrians, and bicyclists.

National Center for Statistics and Analysis

https://cdan.dot.gov/

The National Center for Statistics and Analysis (NCSA) FARS and GES/CRSS query reporting tools and traffic safety publications

National Emergency Medical Services Information System

https://nemsis.org/view-reports/

The National Emergency Medical Services Information System (NEMSIS) is the national system used to collect, store, and share EMS data from the U.S. States and Territories. NEMSIS develops and maintains a national standard for how patient care information resulting from prehospital EMS activations is documented. This data may be used to supplement crash data to understand health and safety outcomes that are not captured in crash reports.

A Practitioner's Guide for Advancing Health Equity
https://www.cdc.gov/nccdphp/dch/pdf/healthequityguide.pdf

EPA EJScreen: Environmental Justice Screening and Mapping Tool
https://www.epa.gov/ejscreen

2020 Census Population Data
https://www.census.gov/programs-surveys/popest/technical-documentation/research/evaluation-estimates/2020-evaluation-estimates.html

VISSIM
https://www.myptv.com/en/mobility-software/ptv-vissim
VISSIM digitally reproduces the traffic patterns of all road users. This is used for the evaluation and improving the performance of traffic facilities, and help address issues related to congestion and emissions.

AIMSUN
https://www.aimsun.com/about-aimsun/
AIMSUN is a multi-resolution, multi-modal modelling tool used to simulate mobility at scales from regional down to individual segments and intersections.

Synchro
https://www.trafficware.com/synchro-studio.html
Synchro is utilized for macroscopic analysis and optimization. It supports the Highway Capacity M’nual's (H^{CM}) 6th Edition, 2010 and 2000 for signalized intersections, unsignalized intersections, and roundabouts. It is used for determining intersection capacity and signal optimization.

SimTraffic
https://www.trafficware.com/synchro-studio.html
SimTraffic performs micro-simulation and animation of vehicular and pedestrian-related traffic, where individual vehicles are modelled and displayed traversing a street network. SimTraffic models signalized and unsignalized intersections, as well as freeway sections with multiple vehicle types.

Highway Capacity Software

https://mctrans.ce.ufl.edu/highway-capacity-software-hcs/

The Highway Capacity Software (HCS) implements the methods and procedures documented in the Highway Capacity Manual (HCM). It can be used to support both planning and operational level analyses for surface streets, including intersections, arterials, and freeways. As HCS uses a macroscopic approach to traffic modelling is requires relatively fewer inputs and less time for calibration.

Regional Integrated Transportation Information System

https://ritis.org/

From the Regional Integrated Transportation Information System (RITIS) website: “"RITIS is a situational awareness, data archiving, and analytics platform used by transportation officials, first responders, planners, researchers, and more. RITIS fuses data from many agencies, many systems, and even the private sector—enabling effective decision making for incident response and planning. Within RITIS are a broad portfolio of analytical tools and features. Ultimately, RITIS enables a wide range of capabilities and insights, reduces the cost of planning activities and conducting research, and breaks down the barriers within and between agencies for information sharing, collaboration, and coordina”ion."

INRIX

https://inrix.com

INRIX provides traffic data insights by analyzing data from both road sensors as well as vehicles regarding traffic conditions, weather, and road incidents. It has uses for various transportation applications including real-time parking and traffic, and monitoring the deployments of autonomous vehicles such as providing real-time traffic information to make better decisions about transportation, such as when to leave for work or school, which route to take, and how to avoid traffic congestion. With regards to traffic management and congestion, INRIX data aims to help identify and address congestion hotspots, optimizing traffic signals, and managing incidents.

Wejo

http://www.wejo.com

Wejo[2] is a platform to share and access connected vehicle data. Data products include historic traffic patterns, real-time traffic intelligence, vehicle movements, driving events, journey

[2] Wejo filed for bankruptcy in May, 2023. At the time of this report it is unclear if Wejo will emerge under new ownership or cease operations.

intelligence, traffic intelligence, intersection performance, waypoints, origin-destination studies, and points of interest. As this dataset is collected from vehicles rather than fixed locations or agencies it can provide a broad snapshot regarding traffic flow, and congestion, and used to better manage safety and operations.

Tool for Operations Benefit Cost Analysis

https://ops.fhwa.dot.gov/plan4ops/topsbctool/index.htm

Currently in version 4.0, the Tool for Operations Benefit Cost Analysis (TOPS-BC) is a sketch-planning level decision support tool developed by the FHWA Office of Operations. It is intended to provide support and guidance to transportation practitioners in the application of benefit/cost analysis (BCA) for a wide range of Transportation System Management and Operations (TSMO) strategies. The tool was developed based on guidance and input from planning and operations practitioners with the primary purpose to help in screening multiple TSMO strategies and for providing "order of magnitude" BCA estimates.

Highway Safety Manual

https://www.highwaysafetymanual.org/Pages/default.aspx

The Highway Safety Manual (HSM), first published in 2010 and developed by AASHTO allows practitioners to incorporate a quantitative safety analysis in transportation planning and design process. A supplement, published in 2014, incorporates additional methods for freeway analyses; the second edition - which include additional and updated research - is currently expected to be published in 2025. MDOT has invested considerable time and resources into researching and implementing Michigan-specific safety performance functions (SPF) to better represent the facilities and conditions of Michigan roadways. These have shown to be more reflective of the network in Michigan when compared to using the original HSM SPFs and calibrating them for local conditions. Spreadsheets are available to implement the original HSM SPFs for Rural Two-Lane Roads, Rural Multilane Highways, and Urban and Suburban Arterials. Other states that have developed their own spreadsheets for implementing the HSM include Pennsylvania, Ohio, Louisiana, and Illinois.

Enhanced Interchange Safety Analysis Tool

https://www.highwaysafetymanual.org/pages/tools.aspx

The Enhanced Interchange Safety Analysis Tool (ISATe) is a spreadsheet-based tool to implement the Part C predictive methods of the HSM (more specifically the freeway segments and speed-change lanes in HSM Chapter 18 and the ramps and ramp terminals in HSM Chapter 19). MDOT has partial calibration factors for use with ISATe (not all facility types have calibration factors available) though there have not been Michigan-specific freeway SPFs developed.

Interactive Highway Safety Design Model

http://www.ihsdm.org/wiki/Welcome

FHWA has developed a freely available software program called the Interactive Highway Safety Design Model (IHSDM). The 'HSDM's crash prediction module (CPM) includes the latest analytical methods from Part C of the HSM including the freeway analysis supplement. IHSDM also includes additional safety evaluation modules including the Policy Review Module, Design Consistency, Traffic Analysis, Intersection Review, and Driver/Vehicle Modules. IHSDM aims to improve safety by helping identify design features that reduce the frequency and severity of crashes and improves operational efficiency by identifying features that improve traffic flow and reduce congestion. Using the IHSDM can be partially automated by importing alignments and features from a CAD design file however many of the HSM inputs need to be manually entered. The IHSDM does not automatically include state-specific SPFs (such as those developed by MDOT).

Intersection Control Evaluation (ICE)

https://safety.fhwa.dot.gov/intersection/ice/

ICE is a data-driven performance-based framework to screen intersection alternatives and identify an optimal solution. Adoption of an ICE policy aims to implement safer, more balanced, and more cost-effective solutions with consistent documentation to support transparency in decision making. Tools to aid in implementing an Intersection Control Evaluation include the Safety Performance for Intersection Control Evaluation (SPICE, https://www.fhwa.dot.gov/exit.cfm?link=http://www.cmfclearinghouse.org/resources_selection.cfm) and the Capacity Analysis for Planning of Junctions (CAP-X, https://www.fhwa.dot.gov/exit.cfm?link=http://www.cmfclearinghouse.org/resources_selection.cfm)

Roadsoft

http://roadsoft.org/

Roadsoft is a software suite developed by Michigan Technological University and designed to aid practitioners with asset data and analysis for transportation. Different modules provide users with tools to collect, store, and report on data for multiple purposes including condition, safety, maintenance management, and performance reporting. This suite of tools is provided at no cost to local road agencies in Michigan. Per the documentation, two safety modules include the Crash Module, which "allows you to review and analyze imported crash data in conjunction with RoadSoft's Safety Analysis tools. It allows you to analyze up to 10 years of crash data taken from redacted incident reports"; the Safety Analysis Tools indicate that "users can take advantage of the Safety Analysis tools to filter, sort, and analyze patterns in the crash data using network-screening algorithms."

Michigan Traffic Crash Facts

https://www.michigantrafficcrashfacts.org/

The Michigan Traffic Crash Facts (MTCF) website is an online repository that allows users to access and query official Michigan crash data. The Data Query Tool allows users to interrogate the data and filter the results, which can be viewed in a variety of maps, tables, lists, and charts. The original (redacted) police reports may also be downloaded for review. The site also hosts publications with crash statistics dating back to 1952 to aid in investigating changes over time.

MSP Numetric

https://msp.numetric.com/

Numetric hosts the Michigan State Police's online crash database. It combines a GIS interface with search, network screening, and safety analysis.

Highway Performance Monitoring System

https://www.fhwa.dot.gov/policyinformation/hpms.cfm

The Highway Performance Monitoring System (HPMS) is a national-level highway information system that includes data on the extent, condition, performance, use, and operating characteristics of the US' highways. Initially developed in 1978 (and replacing prior biennial condition studies) it has been regularly modified in the subsequent years. It contains data about pavement and bridge condition, traffic volumes, speeds and travel time, and crashes. HPMS provides a national snapshot, so it may be used for intra- and inter-state analyses.

MDOT Traffic Monitoring Program

https://www.michigan.gov/mdot/programs/planning/asset-mgt/traffic-monitoring-program

MDOT Data Collection and Reporting unit coordinates the collection, analyses, and summaries of detailed traffic data and travel information for federal-aid roads in Michigan, with a limited amount of additional reporting for other local roads.

Context-Sensitive Solutions Spreadsheet Tool

As a part of a companion project (34), a decision-support tool was developed to assist MDOT staff in making planning- and design-level decisions that are multi-modal, performance-based, and context-sensitive. The tool, shown in Figure 28, uses Visual Basic for Applications (VBA) to integrate high-level qualitative (e.g., context) and quantitative (e.g., speed limit, traffic volume) data as input and yield potential solutions that provide accommodation for pedestrians and bicyclists in consideration of constraints introduced by these inputs.

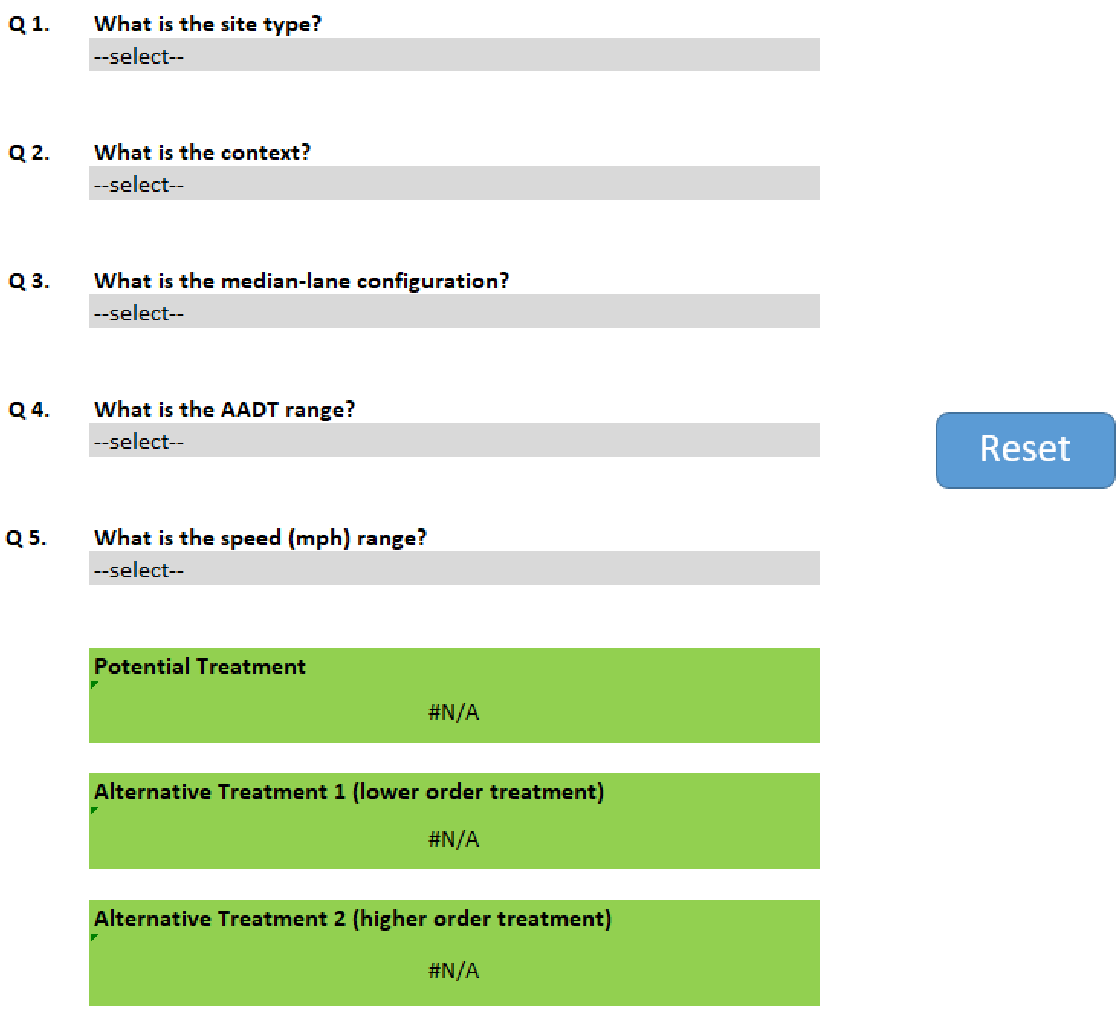

Figure 28 - Pedestrian Bicyclist Facility Selection Tool- Interface

The tool is based upon national guidance, including the Federal Highway Administration *STEP Studio* (31), the United States Department of Transportation *Bikeway Selection Guide* (35), and the National Association of City Transportation Officials *Urban Bikeway Design Guide* (33). The majority of these guidelines are based on quantitative metrics. Additional nuance is provided by considering differences across contextual environments, including the integration of guidance documents, such as the MDOT *Multi Modal Development and Delivery Guidebook* (32).

The VBA tool is comprised of a series of five questions, with the response to each question serving as an input to a series of decision matrices. These questions were developed in consultation with MDOT and consider various site-specific factors that reflect the relative priority that is given to pedestrian and bicyclist needs in consideration of the degree of risk posed to non-motorized users, as well as anticipated non-motorized traffic volumes. The questions are answered using the pull-down menus that are built into the VBA tool, as illustrated in Figure 28.

Separate decision matrices were developed for four scenarios/facility types of interest: (1) pedestrian segments; (2) bicycle segments; (3) midblock crossings; and (4) intersection crossings. For each facility type, the corresponding matrices identify potential treatments that are appropriate based upon AADT, speed limit, context, number of lanes, and median type. In general, scenarios that present higher risks for non-motorized users (e.g., higher AADT, higher speed limits) lead to treatments that provided greater protection to such users.

After selecting a response for each of these five questions, a series of prospective treatments that could be implemented at the site under investigation are displayed to the user. This includes a default "potential treatment" that was identified using various guidance documents, as well as one "lower-order treatment" (i.e., a treatment that is generally lower cost or less extensive) and one "higher-order treatment" (i.e., a treatment that is higher cost or more extensive).

This VBA tool is expected to be most useful during the early stages of a project, especially during scoping and project development. During these stages, it is generally easier and more economical to accommodate pedestrian- and bicyclist-friendly treatments. The tool is also designed such that it is complementary to other resources, such as the multimodal tool developed for use by MDOT and the Southeast Michigan Council of Governments (SEMCOG).

The tool will assist MDOT and other road agencies in applying a consistent data-driven approach to highway design that is multimodal, performance-based, and context-sensitive. This may include project prioritization, detailed modal analyses, and design at various stages of the project development process. The tool is applicable across various contexts and considers a diverse range of readily available qualitative and quantitative data.

AASHTO Mechanistic-Empirical Pavement Design

https://me-design.com/

The Mechanistic-Empirical Pavement Design Guide describes a pavement design methodology derived from engineering mechanics and has been tested and validated with performance data from multiple real-world road tests. The benefit of this approach is that it helps accurately describe the in-situ materials which form the foundation of the pavement structure.

Planning and Environmental Linkages

https://www.environment.fhwa.dot.gov/env_initiatives/pel.aspx

The Planning and Environmental Linkages (PEL) process is a collaborative and integrated approach to transportation decision-making that considers environmental, community, and economic goals early in the transportation planning process. The PEL process may help agencies identify and address potential environmental impacts early in the planning process, develop more environmentally sustainable transportation solutions, build relationships with stakeholders and the public, and improve the efficiency of the transportation planning process. In particular, the process aims to identify a transportation problem or issue, gather information regarding various impacts of potential solutions, develop a range of alternatives, and evaluate the alternatives and select the preferred solution.

7. Review of Design Exceptions and Variances

The Federal Highway Administration has standards that apply to all projects on the National Highway System (NHS). However, after the passage of the surface transportation funding bill passed in 2012 ("Moving Ahead for Progress in the 21st Century Act", or MAP-21) it was recognized that there was a need to address how to apply design standards and design exceptions in the development of highway projects. FHWA has encouraged flexibility and a context-sensitive approach which considers a full range of project needs and impacts to communities and environments. When a deviation from a standard is proposed, the justification for this deviation and proposed impacts need to be thoroughly analyzed and documented.

Per FHWA's guidance on NHS Design Standards, documentation for design exception requests should describe all of the following (30):

- Specific design criteria that will not be met;
- Existing roadway characteristics;
- Alternatives considered;
- Comparison of the safety and operational performance of the roadway and other impacts such as right-of-way, community, environmental, cost, and access for all modes of transportation;
- Proposed mitigation measures; and
- Compatibility with adjacent sections of roadway.

To assess the cost impact of meeting full design standards, Design Exceptions and Design Variance (DE and DV) requests for 4 years from January 2018 through March 2022 were analyzed. These forms were provided by MDOT to complete a representative analysis and may not include all DE and DV forms throughout the state of Michigan during the study period.

DE AND DV's are required for a project when MDOT's design criteria cannot be met for the controlling design elements. DE and DV's should be addressed as early as possible in the design phase, preferably during the scoping process. Whether the request is considered a DE or DV depends on the controlling element and the design speed. The details are shown in Table 12 below:

Table 12 - Comparison between Design Exceptions and Design Variances, from Michigan Road Design Manual

Non standard design element	Applicability of Design Exception (DE) or design variance (DV)	
	Design Speed	
	⩾ 50 MPH	⩽ 50 MPH
Design Speed < Post Speed	DE	DE
Lane Width*	DE	DV
Shoulder Width	DE	DV
Horizontal Curve Radius*	DE	DV
Superelevation Rate*	DE	DV
Superelevation Transition*	DV	DV
Maximum Grade*	DE	DV
Stopping Sight Distance (Horizontal and Vertical) *	DE	DV
Cross Slope	DE	DV
Vertical Clearance	DE	DE
Design Loading Structural Capacity	DE	DE
Ramp Acceleration / Deceleration Length*	DV	DV

*Values based on design speeds less than posted.

Within the study area, as shown in Table 13, a total of 213 variances were requested during the four years from 2018 through 2021. Of these, data on the relative percentage cost increase (percent of base cost) was available for 141 crashes and data on the total cost increase (in dollars) to design to the standard was available for 161 requests. The elements with the highest median cost increase were Superelevation Rate, Horizontal Curve Radius, Vertical SSD (K), Vertical Clearance, and Shoulder Width. These elements resulted in a large total cost increase, a large cost increase relative to its original cost, or both.

It's important to note that the data primarily consisted of Design Exceptions as opposed to Design Variances. Of the 141 requests containing the relative cost increase and 161 requests containing the total cost increase, only two (2) and 23 were Design Variances, respectively. The remaining 139 and 138 were Design Exceptions. This could be attributed to the fact that most requests were for highway projects and other higher-speed roads as these facilities generally have higher standards compared to lower-speed or lower-volume facilities.

Due to insufficient levels of cost data provided for Superelevation Transitions and Ramp Lengths within the analyzed DE and DV forms, it is not possible to consider the significance of their cost increases in this analysis.

Table 13 - Percentage and Total Cost Increases by Variance Type

Element	Total Count	Median cost increase	
		Percent (%)	Dollars ($)
Superelevation Rate			$2,580,000
Superelevation Transition	18	N/A	$10,235,000
Horizontal Curve Radius	7	31.23%	$932,150
Horizontal SSD	20	8.25%	$3,126,000
Vertical SSD (K)	15	18.65%	$1,289,275
Vertical Clearance	9	43.57%	$5,000,000
Shoulder Width	49	19.49%	$2,914,675
Lane Width	16	9.13%	$500,000
Cross Slope	36	3.61%	$580,000

Element	Total Count	Median cost increase	
		Percent (%)	Dollars ($)
Maximum Grade			$5,998.000
Design Loading Structural Capacity	1	1.67%	$340,000
Ramp Acceleration and Deceleration Lengths	12	N/A	$15,542,534.50
Deck Replacement	2	N/A	N/A
Total	213		

Source: MDOT

As shown in Figure 29, the highest median costs by total cost were due to Superelevation Transitions, Maximum Grades, and Vertical Clearances. It's important to keep in mind that in the studied time range, Maximum Grade, Design Loading Structural Capacity, and Ramp Lengths had less than three cost data points each, as shown in Table 13.

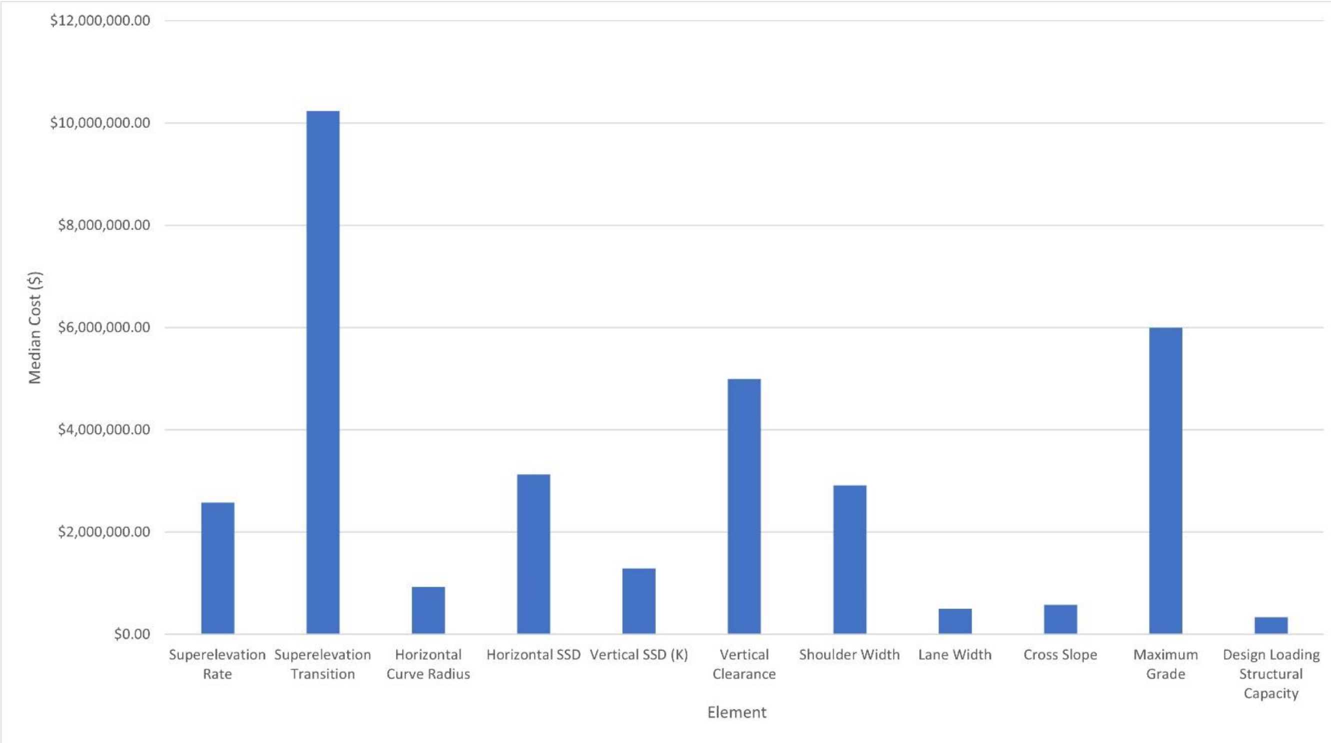

Figure 29 - Median Cost by Element

Table 14 details a more complete set of data of the DE and DV requests. Most of the total increased cost was due to three elements – Superelevation Rate, Horizontal SSD, and Shoulder Width accounted for 71.86% of the roughly $2.2 billion of cost increases. Relative to their original cost, the most expensive elements were Vertical Clearance, Maximum Grade, and Horizontal Curve Radius, with median cost increases of 43.57%, 42.06%, and 31.23%, respectively. Figure 30 and Figure 31 detail the total added cost created by each element and the relative cost increases created by each element, respectively.

Table 14 - Median Cost by Element Total Variance Request Cost Data (2018-2021)

Element	% Of total quant	% cost count	Median cost increase (%)	$ Cost count	Median Cost increase ($)	Total element cost	% of total cost
Superelevation Rate	27	12	15.86%	19	$2,580,000	$461,930,108.42	21.23%
Superelevation Transition	18	0	N/A	3	$10,235,000	$47,135,000.00	2.17%
Horizontal Curve Radius	7	6	31.23%	7	$932,150	$29,177,876.19	1.34%
Horizontal SSD	20	16	8.25%	19	$3,126,000	$566,240,040.63	26.03%
Vertical SSD (K)	15	14	18.65%	14	$1,289,275	$112,352,022.89	5.16%
Vertical Clearance	9	9	43.57%	9	$5,000,000	$230,370,287.00	10.59%
Shoulder Width	49	48	19.49%	48	$2,914,675	$535,226,329.78	24.60%
Lane Width	16	11	9.13%	13	$500,000	$24,740,194.75	1.14%
Cross Slope	36	23	3.61%	25	$580,000	$130,869,514.97	6.02%
Maximum Grade	1	1	42.06%	1	$5,998.000	$5,998,000.00	0.28%
Design Loading Structural Capacity	1	1	1.67%	1	$340,000	$340,000	0.02%
Ramp Acceleration and Deceleration Lengths	12	0	N/A	2	$15,542,534.50	$31,085,069.00	1.43%
Deck Replacement	2	0	N/A	0	N/A	N/A	0.00%
Total	213	141		161		$2,175,464,443.63	

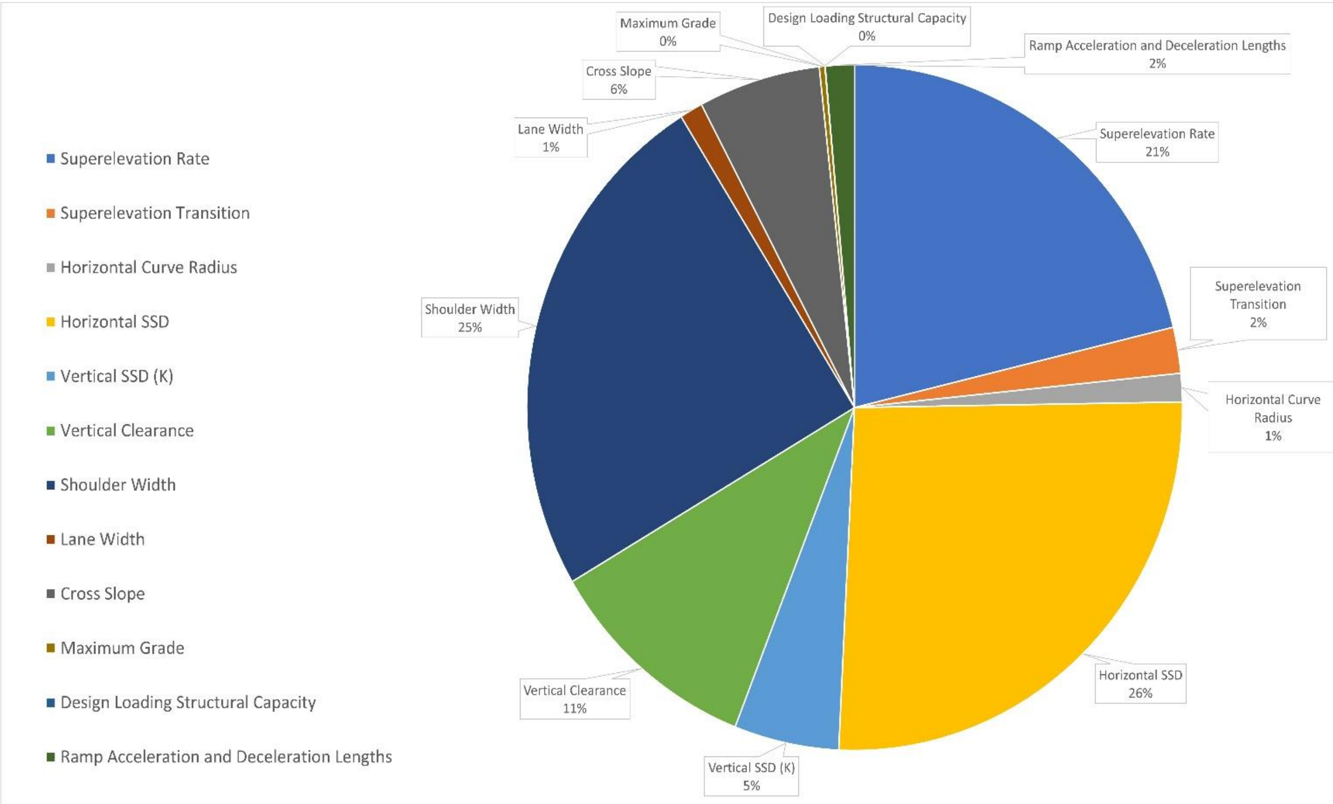

Figure 30 - Total Cost by Element

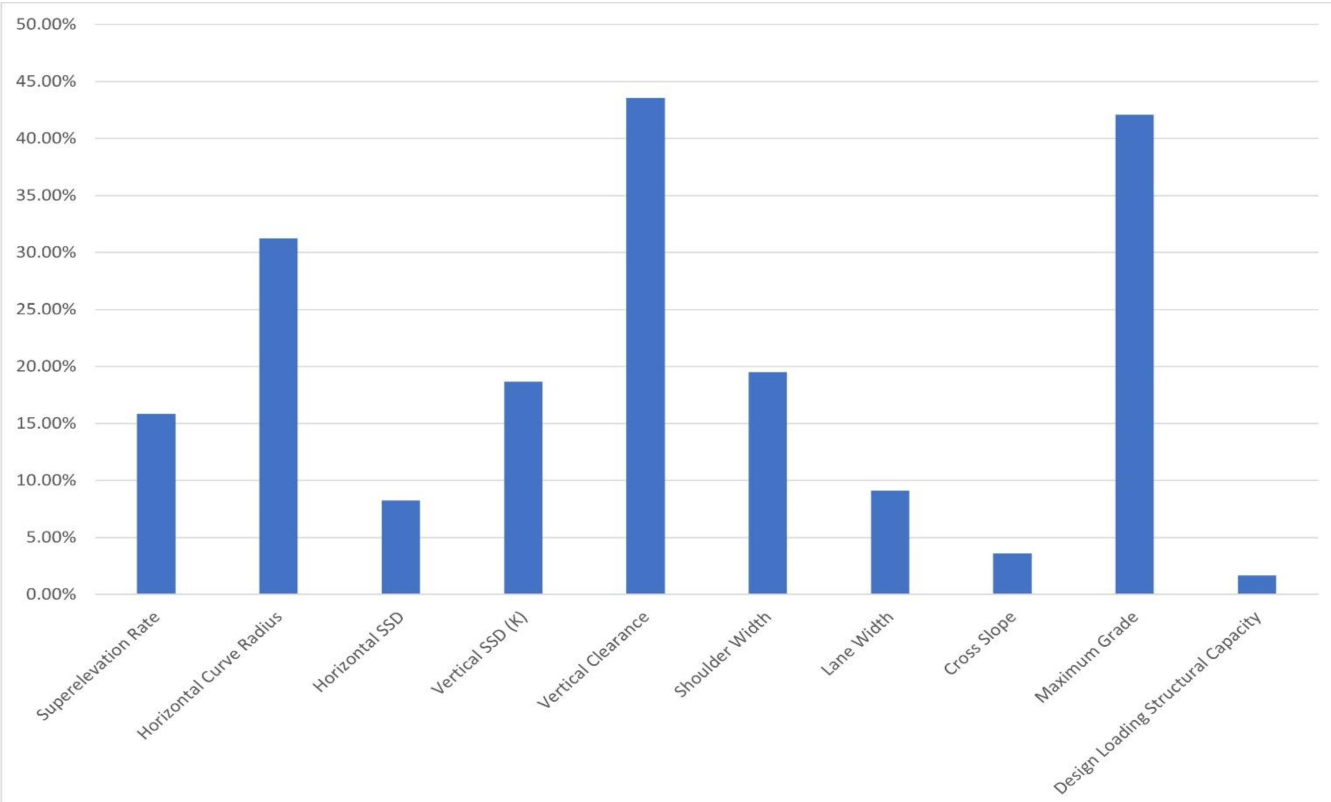

Figure 31 - Percentage Cost Increase Relative to Original Cost

While cost may not be the ultimate factor when determining the need for a DE or DV, they may have a significant impact in a project. Relative to the original costs, accommodating the needed horizontal curve radius, vertical clearance, or maximum grade could require significant earthwork, right-of-way, or increase to the project limits, all of which may add to the duration of a project and add additional environmental and other reviews. The key elements of each DE and DV need to be listed on the Design Exception Request and Design Variance Request forms, and the safety impacts need to be analyzed related to these deviations. Whether the proposed changes improve compliance with the standard, stay the same, or move further from the requirement needs to be clearly documented and the standard or standards not being met need to be recorded.

The potential safety performance of the most common request (shoulder width) can be directly modelled using the Highway Safety Manual; the trade-offs between reducing shoulder width may be compared to both the historical performance of the facility (e.g. has there been a history of crashes related to the requested DE or DV?) as well as against a wider body of similar facilities that were used in developing the associated safety performance function.

These standards may change over time, and even between the development of a project's scope and the ultimate design and construction. Understanding the criteria in place and decisions made throughout the planning and design process are critical for monitoring potential safety and operational concerns which may arise during normal operations or during future maintenance, rehabilitation, or reconstruction projects.

Additional information regarding the basis of design should be included as part of the project's documentation, including version and date of relevant MDOT and federal design manuals and standards (including, but not limited to the MDOT Road Design Manual, AASHTO Green Book, and Manual on Uniform Traffic Devices (MUTCD)) will aid in understanding the project.

8. Conclusions and Recommendations

IT IS PARAMOUNT THAT THE PURPOSE AND NEED FOR EVERY PROJECT SHOULD BE APPROPRIATELY DEFINED AND DOCUMENTED.

PROJECT OBJECTIVES AND NEED STATEMENTS THAT DOCUMENTS THE DEPARTMENT'S PERFORMANCE OBJECTIVES FOR THE PROJECT ARE UNAMBIGUOUS.

A PROJECT AND OBJECTIVE STATEMENT SHOULD BE DEVELOPED AT THE BEGINNING OF THE PROJECT TO CLEARLY DESCRIBE THE GOALS AND EXPECTED OUTCOME OF THE PROJECT AND NOT JUST A PARTICULAR SOLUTION.

This research examined the current practices of PBPD in other states, surveyed other state DOT practitioners for their views on PBPD, spoke with different business units within MDOT, and finally suggests opportunities for MDOT to expand the use of PBPD within Michigan.

As shown above, a common thread from all agencies who have implemented PBPD is the importance of a clear purpose and need statement to be documented as that is the benchmark by which performance-based decision need to be weighed to ensure they align with – or better yet enhance – these objectives.

Having this clear purpose and need statement provides the lens through which other major decisions may be viewed: does the design align with the purpose and need? Does the purpose and need match that of adjacent sections of a corridor, adjacent corridors, or the broader region?

This may pose a challenge for several reasons. As not every project was born from a planning process that includes the development of a formal purpose and need statement; for example (rehab, safety, project expanding from original scope, etc.) it may be more challenging to include performance-based decisions at later stages. From the review of other states and discussions with MDOT business groups, project-specific decisions related to safety or operations may be the most successful at these later stages owing to the tools and processes already in place to analyze related data and consider trade-offs.

Define metrics to measure specific outcomes

"What gets measured gets done" has been attributed to many writers and speakers, though the premise is that gauging progress or success must be in reference to a specific goal or target. This avoids "moving the goal posts" and provides an outcome that all participants in a project or program can strive towards. Using a safety example, this can be a finite outcome such as "zero deaths by 2050" or a progress metric such as "fifty percent reduction in fatalities by 2035". These measures could be either qualitative or quantitative depending on the criteria being assessed.

Define desired outcomes for specific corridors, types of corridors, or regions

A desire of this performance-based focus is to help provide consistency for system managers and users and avoid abrupt transitions between projects, counties, or regions when possible. While certain natural breaks may be unavoidable MDOT may wish to define certain parameters which should be consistent across a specific corridor (e.g. Interstate 94), types of corridors (e.g. all interstates), or within a region or area (e.g. within Bay Region). This will also provide guidance to system managers and designers when deciding which design parameters are sacrosanct and which may be modified to better align with adjacent or regional goals.

Determine projects appropriate for PBPD

While designing to a project's purpose and need should be considered business as usual, not all projects share the same level of size, complexity, or available funding. Additional analyses to further vet additional opportunities to narrow the scope or include performance-based considerations may ultimately cost more in time or funding than is available with no guarantee that they will ultimately result in a changed outcome.

Based on the review of other states and discussions with MDOT business units, projects with primarily safety or operational changes may best be able to maximize the use of PBPD, and larger projects (e.g. those with a larger budget or longer design timeline) may be able to absorb the analyses needed to compare tradeoffs or alternatives.

Improve documentation requirements

Enhanced documentation may be needed to support PBPD. While many relevant items may be contained in different locations in a project file, each type of project (e.g. planning study, PEL study, or project) has a different format and different data needs. For instance, the Title Sheet of a design project will list the version of the MDOT Specifications that apply, and a list of standard plans and special details is listed on the Note Sheets. Special Details are included in the plan set itself, though Standard Plans are included by reference and if they change over time, copies of the older plans may not be available. While these may be accessible internally to MDOT staff, an archive with copies of each iteration of Standard Plan and Special Detail (and the dates they applied to plans) should be developed.

A review of several Planning and Environmental Linkage studies show that the existing conditions are documented, but not the current standards or manuals in place at the time.

A recent change to MDOT's review process is the use of BlueBeam software. This allows a collaborative approach where a session hosts the documents and comments from all users, and the review and validation process notes changes. In anecdotal discussions with design engineers, it was raised that these sessions provide a wealth of information about potential decisions and would be useful for tracking design decisions and changes. These extemporaneous comments and edits are retained even if projects experience staff changes or retirements. Bluebeam or similar collaborative review software should be considered for these tracking features.

To better compare decisions made throughout the lifecycle of the planning and design project, a form should be developed as a single point of reference for inclusion in the project record listing the date of a submittal and the guides, standard plans, and specifications used. These should include plans and specifications not included in the planning or design package; for example, standard plans would be included (since they are included in the design package by reference) though special details would not need to be (as they are included directly in the plans). Other documents that should be listed could include the version of the AASHTO Green Book, Michigan Manual on Uniform Traffic Control Devices (MMUTCD), Michigan Road Design Manual, Drainage Manual, or other reference documents used. An example of a Basis of Design form used in Washington (WSDOT) is included as Appendix C.

Similarly, MDOT should consider updating the Design Exception and Design Variance forms (form numbers DE26 and DV26 at the time of this report). The forms currently ask for information about the specific design criteria that will not rise to standard, however other criteria which may influence these decisions are not listed. For example, if a curve radius does not meet the standard for the needed speed, MDOT Standard Plan R-106x may be referenced, though not the MMUTCD or signing standard plans that would govern how to notify the driving public. In this example, the degree of curvature may affect warning signs used.

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APPENDIX A - ROAD AGENCY SURVEY ON PERFORMANCE-BASED PRACTICAL DESIGN (PBPD)

Michigan State University and WSP Michigan Inc. (WSP) are preparing a synthesis of transportation agency practices as they relate to performance-based practical design (PBPD). This work is being conducted as a part of a research project sponsored by the Michigan Department of Transportation (MDOT), titled "Corridor and Systemwide Application of Performance Based Practical Design (PBPD)".

The objective of this synthesis is to compile current agency practices, recent literature findings, and research-in-progress addressing PBPD as a means for developing and designing roadway projects. As an initial step in the synthesis, this survey was developed to:

- identify existing policies, practices, and guidance as to the application of PBPD;
- prepare an inventory of performance measures that are commonly used by agencies in implementing PBPD; and
- determine the resources that are utilized in estimating and forecasting the potential impacts of PBPD across various performance measures.

This survey is in the form of an online questionnaire (https://forms.gle/ay4585ZKgWeDvF5F6). This Word document may also be filled out directly and emailed to pete@msu.edu. As some aspects of the survey may be germane to other areas, we are hopeful you will coordinate a response with others in your agency where pertinent. If you feel that another person(s) within your agency would be better suited to complete this questionnaire, then please let us know or feel free to forward the survey on to them directly.

We realize that you receive many inquiries like this and that they take up a lot of your time, but the success of this project depends on your input. Therefore, we sincerely appreciate your efforts in sharing your experience with others who can benefit from it. Your response to this survey by **Friday, September 24, 2021** would be very much appreciated. The survey should take approximately 15-30 minutes of your time.

Please feel free to contact me directly if you have any questions or comments. We would also appreciate it if you could share any state-specific guidance your agency may have as it relates to performance-based practical design. These can be emailed to me directly or uploaded at the end of the survey.

Sincerely,

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MSU Foundation Professor
Associate Chair for Graduate Studies
Department of Civil and Environmental Engineering
Michigan State University
428 S Shaw Ln, Room 3559
East Lansing, MI 48824
Phone: (517) 432-1825
E-mail: pete@msu.edu

Contact Information:

Name: ________________________________
Agency/Department: ______________________
Job Title: _____________________________
Phone Number: _________________________
Email Address: _________________________

Performance-Based Practical Design (PBPD) Overview

The Federal Highway Administration (FHWA) defines Performance-Based Practical Design (PBPD) as a decision-making approach that uses quantitative analyses to guide decision-making through the project development process. PBPD modifies the traditional highway design process by taking a "design up" approach where transportation decision makers exercise engineering judgment to build up the improvements from existing conditions to meet both project and system objectives. PBPD uses appropriate performance-analysis tools, considers both short- and long-term project and system goals while addressing project purpose and need. This builds upon related design concepts, including flexibility in design, Context Sensitive Solutions, Practical Design, Asset Management, and Value Engineering.

1. Does your agency's existing guidance and regulatory requirements allow for PBPD or similar practices?

☐ Yes
☐ No
☐ Unsure

2. Given the definition provided above, does your agency have a formal or informal program related to PBPD, or some other similar project development and design philosophy?

☐ Yes, we have a formal PBPD program (examples include: a PBPD policy within your agency; incorporation of PBPD within agency design manuals)
☐ Yes, we have an informal PBPD program (examples include piloting PBPD on select projects, including PBPD within internal guidance documents)
☐ No
☐ Unsure

3. If applicable, please describe how PBPD decisions are made and documented at your agency (e.g., who has the authority to make decisions, what types of documentation are required)?

4. If applicable, please describe how PBPD decisions are approved at your agency (i.e., what does the approval path look like and who at the agency is involved)?

5. For which of these common project types does your agency apply PBPD or similar principles? (Check ALL that apply.)

☐ obtaining design exceptions for lane and shoulder widths;
☐ reducing the number of lanes built as part of major projects;
☐ using alternative shoulder designs;
☐ installing low-cost safety countermeasures, such as signs, rumble stripes, and striping;
☐ selecting alternative designs to lessen right-of-way or environmental mitigation costs;
☐ introducing active traffic management;
☐ modifying interchange designs;
☐ using design exceptions or design variances to fulfill project objectives;
☐ other (please specify):

____

6. When in the project process (e.g., planning, scoping, preliminary design, final design, construction) is the adjacent corridor or network considered? (Check ALL that apply.)

Project Phase	Never	Rarely	Sometimes	Usually	Always
Planning					
Scoping					
Preliminary Design					
Final Design					
Construction					

7. How frequently does your agency utilize PBPD or similar practices at the following levels?

System Level	Never	Rarely	Sometimes	Usually	Always
Project- or site-specific					
Corridor-specific					
System-wide					

8. What are your agency's existing guidelines or policies that describe how to define the purpose and need of improvement projects? If possible, please email the specific document/section that includes this information to pete@msu.edu or upload them at the end of this survey.

9. To what extent does the determination of a project's purpose and need include a consideration of corridor and/or system needs beyond the boundaries of the project?

10. If considerations beyond the boundaries of the project are included, how are changes made to the project after considering the adjacent network or how are the identified priorities of the corridor integrated into the project?

11. Which of these criteria does your agency typically consider in determining the purpose and need of improvement projects? (Check ALL that apply.)

☐Operational performance/level-of-service
☐Safety
☐System reliability
☐Congestion
☐Freight movement/economic vitality
☐Accessibility
☐Life-cycle costs
☐Environmental sustainability
☐Maintenance
☐Adjacent corridor or network needs
☐Other (please specify) ________________________________

12. What specific measures of effectiveness are used to quantify improvements across these criteria?

Criterion	**Specific measures of effectiveness (complete for all that are applicable)**
Operational performance/level-of-service	
Safety	
System reliability	
Congestion	
Freight movement/economic vitality	
Accessibility	
Life-cycle costs	
Environmental sustainability	
Maintenance	
Other (please specify)	
Operational performance/level-of-service	
Safety	
System reliability	
Congestion	

13. What evaluative methods does your agency use to determine whether the performance measures were met (e.g., whether the project was successful in accomplishing its purpose and meeting its need)?

14. Which of these analytical tools does your agency use as a part of its planning and design practices? (Check ALL that apply.)

☐AASHTO Green Book
☐Agency-Specific Design Manual/Guidelines
☐NACTO Urban Street Design Guide
☐Highway Capacity Manual (HCM)
☐Highway Safety Manual (HSM)
☐Simulation Software (e.g., Synchro/SimTraffic, VISSIM, CORSIM, Dynasmart-P)
☐Safety Analyst
☐Interactive Highway Safety Design Model (IHSDM)
☐Other: ____

15. Does your agency employ any of the following practices to help ensure successful implementation of PBPD or similar philosophies?

☐Executives embrace PBPD and communicate this support to all State employees and consultants.
☐A PBPD champion leads implementation throughout all levels of the agency.
☐Policies and guidance are revised as appropriate to include the values of PBPD to facilitate a multi-disciplinary and comprehensive approach to delivering projects under PBPD.
☐Engineers are encouraged and empowered to exercise judgments on projects based on PBPD principles.
☐Engage support from or integrate activities with the FHWA division office during PBPD implementation.

16. Please provide details of any revisions or changes to existing practices that would be necessary or helpful to produce improve your agency's abilities to implement a PBPD approach?

17. If your agency has developed any tools or software to assist with integrating PBPD principles into your design process, please provide a brief explanation and details of these tools below. If possible, please provide a copy of these tools by email to pete@msu.edu or upload them at the end of this form.

18. If your agency has any guidance documents that have been developed, or are used, in support of PBPD or similar programs, please email those to pete@msu.edu or arrange for alternate modes of delivery (e.g., FTP site).

19. If there is any additional information you believe is pertinent to your agency's PBPD or similar activities that has not been captured previously, please provide details here.

APPENDIX B - WASHINGTON (WSDOT) BASIS OF DESIGN FORM

Basis of Design

Project Title:
PIN:
Date:

Practical decision making is a philosophy that considers each situation, aligns with our financially constrained budget environment, and encourages incremental, flexible, and sustainable investments by focusing on identified performance needs and engaging stakeholders at the right time. There are six core principles that capture the essence of practical decision making: • Starts with a clear purpose and need • Considers resource constraints and life cycle cost • Engages stakeholder and looks for partnerships • Considers overall system performance • Considers incremental, phase solutions • Applies innovation and creativity Where the six core principles are incorporated into this form are noted along the right side of this form. Consider all of the core principles as you progress through completing this Basis of Design.
NOTE TO DESIGNERS *There are tips provided in red italics text. This text along with the BOD instructions are intended to help you fill out this document. Delete the red text [including this note] in the final version of the document.*

Related Documents and Technical Reports

Insert a list of documents and reports that were integral to the origination of this project. Include enough information so the document may be found at a later date.

Community Engagement

Community Engagement	*Describe past and planned community engagement.*	Engage Stakeholders

General Project Information

Route Information	**SR**	**NHS (Y/N)**	**Functional Class**	**City**		**County**		Clear Purpose and Need
Project Information	**Begin SRMP**	**End SRMP**	**Budget**	**Funding Sub-Program**	**Posted Speed**	**AADT**	**Truck %**	
Brief Project Description								
Important Project History or Background								
Future and Related Projects								
Major Environmental Considerations	*If an Environmental Review Summary is available, summarize the highlights here. If not, conduct a GIS review of the project area to evaluate the following:* ▪ *Chronic Environmental Deficiencies* ▪ *Climate vulnerability* ▪ *Fish passage barriers* ▪ *Habitat connectivity* ▪ *Historic bridges* ▪ *Noise walls* ▪ *Stormwater retrofits* ▪ *Wetland mitigation sites* ▪ *Other considerations: Are any streams, wetlands, water bodies, or other critical areas present that could be impacted?* *IMPORTANT: Verify information with the Region Environmental Office. Seek ESO assistance if needed.*							

Basis of Design

Project Title:

PIN:

Date:

Section 1) Project Needs		
Baseline Need (BN)	**BN1 Statement:** *Describe the first baseline need* Metric: Target:	Clear Purpose and Need
	Contributing Factors: *What are the contributing factors to each Baseline Need?*	
	BN# Statement: *Describe BN2, BN3, BN4, etc. Delete if not applicable.* Metric: Target:	
	Contributing Factors: *What are the contributing factors to each Baseline Need?*	
Contextual Need (CN)	**CN1 Statement:** *Describe the contextual need* Metric: Target:	Consider Resource Constraints Engage Stakeholders
	Contributing Factors: *What are the contributing factors to each Contextual Need?*	
	CN# Statement: *Describe additional contextual needs using CN2, CN3, CN4, etc. Delete if not applicable.* Metric: Target:	
	Contributing Factors: *What are the contributing factors to each Contextual Need?*	
Safety Analysis	☐ No ☐ Yes *If YES, enter the title and date. If NO enter why it was not needed. See DM Chapter 321 and the Safety Analysis Guide.*	Consider Overall System Performance

Basis of Design

Project Title:
PIN:
Date:

Section 2) Context

Roadway _______ MP _____ to MP _____

[Duplicate this section as necessary to reflect distinct segments with different context]

Multidisciplinary Team Members	*List the agencies, community stakeholders, and divisions involved in determining the context for this project.*		Engage Stake-holders

Land Use Context	**Freeway**	☐ Rural ☐ Urban		☐ Interstate ☐ Non-Interstate			Consider Overall System Performance
	Non-Freeway	Existing	☐ Rural ☐ Suburban ☐ Urban ☐ Urban Core				
		Future	☐ Rural ☐ Suburban ☐ Urban ☐ Urban Core				

Transportation Context

Bicycles

Accommodation	Prohibited	Low	Med	High	Involve Multidisciplinary Team Members
Current	☐	☐	☐	☐	
Future	☐	☐	☐	☐	
Comments	*Describe any special design considerations that apply. Utilize the Context and Modal Accommodation Report (CMAR) to fill in this information.*				

Primary User Type	Interested but Concerned	Somewhat Confident	Highly Confident	Involve Multidisciplinary Team Members
Current	☐	☐	☐	
Future	☐	☐	☐	
Comments	*Record the most common user type anticipated. For definitions of User Types see the FHWA Bikeway Selection Guide (Page 12-13). See Design Manual Chapter 1520 for guidance on the application of User Types in design.*			

Pedestrians

Accommodation	Prohibited	Low	Med	High	Involve Multidisciplinary Team Members
Current	☐	☐	☐	☐	
Future	☐	☐	☐	☐	
Comments	*Describe any special design considerations that apply here. Utilize the Context and Modal Accommodation Report (CMAR) to fill in this information.*				

Freight

Classification	T-1	T-2	T-3	T-4	T-5	See Truck Freight Classification
Current	☐	☐	☐	☐	☐	
Future	☐	☐	☐	☐	☐	
Comments	*Coordinate with Multidisciplinary Team Members. Describe any special design considerations that apply here.*					

Transit

Fixed route type	None	Local	Limited Stops	Express	Transit Agencies
Current	☐	☐	☐	☐	*List all transit agencies that operate within the project limits.*
Future	☐	☐	☐	☐	
Comments	*See DM 1102.03(5). Coordinate with Multidisciplinary Team, describe special design considerations. Utilize the Context and Modal Accommodation Report (CMAR) to fill in this information.*				

Main Street Highway

☐ No ☐ Yes

Has the location been designated a Main Street highway (see State Highways as Main Streets: A Study of Community Design and Visioning)? Consult with the region planning office when making this determination. Refer to case studies in Washington's Complete Streets & Main Street Highways Program for design concepts consistent with State Highways as Main Streets.

Complete Streets

☐ No ☐ Yes

Does the local jurisdiction have a Complete Street ordinance? Consult with the region planning office and local plans or ordinances when making this determination. See Design Manual Chapter 1231 for design criteria that are consistent with complete street goals.

Existing Design Variance

Are there existing Design Variances within the Project Limits? ☐ No ☐ Yes

If YES, can this project correct any of the existing design variances?

Request a list of known variances from your ASDE. Go through this list and see if you have the opportunity to correct or change the elements associated with the design variance.

Basis of Design
Project Title:
PIN:
Date:

<table>
<tr><th colspan="6">Section 3) Design Controls</th></tr>
<tr><td colspan="6">Roadway _______ MP ______ to MP ______
[Duplicate this section as necessary to align with the Context described in Section 2]</td></tr>
<tr><td>Design Year</td><td colspan="4">Design year and selection rational</td><td>Incremental Phased Solutions</td></tr>
<tr><td rowspan="8">Modal Accommodation Priorities
Priority 1,2,3 etc. 1 is highest</td><td rowspan="2">Mode</td><td colspan="2">Priority</td><td rowspan="2">Notes</td><td rowspan="17">Consider Overall System Performance</td></tr>
<tr><td>Current</td><td>Future</td></tr>
<tr><td>Automobiles</td><td></td><td></td><td></td></tr>
<tr><td>Transit</td><td></td><td></td><td></td></tr>
<tr><td>Freight</td><td></td><td></td><td></td></tr>
<tr><td>Pedestrians</td><td></td><td></td><td></td></tr>
<tr><td>Bicyclists</td><td></td><td></td><td></td></tr>
<tr><td>Other</td><td></td><td></td><td></td></tr>
<tr><td>I/S Design Vehicle</td><td colspan="4">Describe the intersection design vehicles for all intersections that will be modified by the project. State the Design Vehicle for each leg of the intersection.</td></tr>
<tr><td>Terrain</td><td colspan="4">☐ Level ☐ Rolling ☐ Mountainous</td></tr>
<tr><td rowspan="3">Access Control</td><td>Existing</td><td colspan="3">See Access Master Plan Database</td></tr>
<tr><td>Planned</td><td colspan="3">See Access Master Plan Database</td></tr>
<tr><td>Proposed</td><td colspan="3"></td></tr>
<tr><td>Target Speed</td><td colspan="4">State the Target Speed and how you it was determined.</td></tr>
</table>

Basis of Design

Project Title:

PIN:

Date:

Section 4) Alternative Analysis			
		Alternative Name and Description	Consider Resource Constraints and Life Cycle Cost Consider Incremental Phased Solutions Apply Innovation and Creativity
Alternatives Considered **(circle the preferred alternative)**	**A**	*Provide a brief description of each alternative considered. Talk about key elements of the alternative that came into consideration when selecting the preferred alternative. Include cost.*	
	B		
	C		
	D		
Preferred Alternative ____ was selected because: *Describe why you selected the preferred alternative. Attach copies or provide information (title, date, etc.) regarding alternatives analysis, trade-offs comparison, or similar exercises that have been completed for this project, such as an ALTERNATIVES COMPARISON TABLE. If the prime considerations for selecting an alternative were documented in another document, you do not need to go into detail here. Instead, provide a summary, reference the document, and include it in the Design Approval.*			

Basis of Design

Project Title:
PIN:
Date:

Section 5) Design Elements Changed

*For each design element below, identify the design elements that will have dimensions changed in the **preferred alternative** for each alignment or location. You can group alignments into a single location if desired. You may need to add or delete columns.*

Design Element	Alignment #1	Alignment #2	Alignment #3	Alignment #4	Alignment #5	Alignment #6
1. Lane						
2. Median / Buffer						
3. Shoulder						
4. Streetside / Roadside Zone						
5. Pedestrian Facility						
6. Bicycle Facility						
7. Bridges and Buried Structures						
8. Horizontal Alignment						
9. Vertical Alignment						
10. Cross Slope						
11. Side Slope						
12. Clear Zone						
13. Barrier, Guardrail & Rumble Strips						
14. Signals, Illumination, and ITS						
15. Signing and Delineation						
16. On/Off Connections						
17. Intersection / Ramp Terminal						
18. Road Approaches						
19. Roundabout						
20. Access Control						

Prepared by	
______________________________	______________
[Insert name of Project Engineer or person who oversaw the development of the BOD] *[Insert title]* *[Insert name of Region/Program]*	**Date**
Approval Signature	
______________________________	______________
[Insert name of Region/Program designated signee] *[Insert title]* *[Insert name of Region/Program]*	**Date**
Concurrence Signature	
______________________________	______________
[Insert name of ASDE. If not applicable, delete this signature block.] **Assistant State Design Engineer** **Headquarters**	**Date**

APPENDIX C – MDOT PERFORMANCE BASED PRACTICAL DESIGN DRAFT GUIDANCE MEMO

Performance Based Practical Design (PBPD) Guidance

MDOT
Michigan Department of Transportation

DRAFT

January 4, 2021

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Engineering Manual Preamble

This manual provides guidance to administrative, engineering, and technical staff. Engineering practice requires that professionals use a combination of technical skills and judgment in decision making. Engineering judgment is necessary to allow decisions to account for unique site-specific conditions and considerations to provide high quality products, within budget, and to protect the public health, safety, and welfare. This manual provides the general operational guidelines; however, it is understood that adaptation, adjustments, and deviations are sometimes necessary. Innovation is a key foundational element to advance the state of engineering practice and develop more effective and efficient engineering solutions and materials. As such, it is essential that our engineering manuals provide a vehicle to promote, pilot, or implement technologies or practices that provide efficiencies and quality products, while maintaining the safety, health, and welfare of the public. It is expected when making significant or impactful deviations from the technical information from these guidance materials, that reasonable consultations with experts, technical committees, and/or policy setting bodies occur prior to actions within the timeframes allowed. It is also expected that these consultations will eliminate any potential conflicts of interest, perceived or otherwise. Michigan Department of Transportation (MDOT) Leadership is committed to a culture of innovation to optimize engineering solutions.

The National Society of Professional Engineers Code of Ethics for Engineering is founded on six fundamental canons. Those canons are provided below.

Engineers, in the fulfillment of their professional duties, shall:

1. Hold paramount the safety, health, and welfare of the public.
2. Perform Services only in areas of their competence.
3. Issue public statement only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, reasonably, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

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Performance Based Practical Design

The Federal Highway Administration (FHWA) has defined Performance Based Practical Design (PBPD) as a decision-making approach that uses quantitative analyses to guide decision-making through the project development process. It is the combination of Practical Design and Performance-Based Design encompassing the what (economic efficiency) and the how (performance-based, data-driven methodology), either of which is incomplete without the other. The use of data is stressed in the data-driven performance measures in Moving Ahead for Progress in the 21st Century Act (MAP-21) legislation.

The general premise of PBPD is that proposed improvements should be targeted and right sized based on project specific goals and needs. This philosophy places less emphasis on strict adherence to standards and more significance on safety and mobility performance. PBPD needs to be utilized in every step of the project development process from planning/scoping to final design. While applicable to any project and can occur at various phases of the project development process some projects will have limited application while more complex such as a total reconstruction will have more opportunities for PBPD applications.

PBPD helps roadway agencies better manage transportation investments and serve system-level needs and performance priorities with limited resources. Building upon Context Sensitive Solutions, flexibility in design, Practical Design, Asset Management, Multi Modal Development and Delivery and Value Engineering, PBPD helps agencies expand the focus from cost-saving, short-term solutions to improving and evaluating overall system performance. With this premise, PBPD can either be spot, project, corridor or system based.

With PBPD a roadway agency can address and achieve various transportation system goals including but not limited to:

- Minimizing fatalities and serious injuries
- Providing reasonable travel times
- Providing for the economical, efficient, and safe movement of goods to and from markets
- Maximizing the long-term benefits received for each state transportation investment, and
- Minimizing impact on the environment

PBPD is a design up philosophy that makes the necessary improvements to a roadway or structure to address specific performance issues. The goal of PBPD is to fix what is broken and to not unnecessarily spend scarce resources solely for the purpose of meeting published standards when those deficient features defined per standards and guidance are not causing safety, mobility, reliability or similar problems. By scrutinizing each element of a project's scope relative to value, need, and urgency, a PBPD approach seeks a greater return on infrastructure investments.

The building blocks of PBPD will be as follows:

- Safety will not be compromised;
- For most projects, the minimum standard will be the existing condition;
- Project scoping should focus on addressing specific problems supported by data;
- Design solutions should focus on adherence to the project's scoping package;
- Solutions should be an optimized combination of mobility, operations and other modes;
- Designs should be consistent with the context of the corridor;
- Designs should strive to maximize benefit/cost.

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Design

PBPD is a “design up” philosophy rather than the traditional approach to make every facet of a facility meet every standard even when those deficient standards (as defined by manuals) are not causing any mobility, reliability or safety problems.

PBPD during the design phase is typically associated with meeting specific geometric design standards and guidelines. Its application requires a departure from the traditional thinking that meeting design standards is a metric, either formally or informally, to measure the success of a given design. Meeting standards is a worthwhile goal, however, in many instances the cost of meeting all the design standards can be prohibitively expensive or impactful; sometimes to upgrade substandard geometric features that are not causing undue problems. The fact that new design values and concepts are presented in manuals such as the *A Policy on Geometric Design of Highways and Streets* does not imply that existing streets and highways are unsafe, nor does it mandate the initiation of improvement projects. Design concepts and criteria in such policies are intended for use when designing new construction projects on new location or designing reconstruction projects on an existing location. Projects on existing roads particularly call for a flexible, performance-based approach to design. *A Policy on Geometric Design of Highways and Streets* encourages flexible design, which emphasizes the role of the planner and designer in determining appropriate design dimensions based on project-specific conditions and existing and future roadway performance more than on meeting specific nominal design criteria. The emphasis of project decisions must be based on the critical examination of geometric elements, not changing parameters outside the control of the department during the design process such as posted speed limits. Select or size elements that serve priority needs. Reduce or eliminate those that do not.

Exercise of design flexibility may, in some cases, involve leaving some design elements unchanged, if they are performing well, even if they do not fully meet the design criteria generally used in new construction. In some cases, it may be desirable to reduce the dimensions of some design elements, so that other aspects of performance can be improved. For example, shoulder widths might be decreased in some cased to provide space for an additional travel lane or a bicycle lane. The effects of such design changes on all aspects of performance should be assessed as part of the design process.

Design flexibility does not mean that designers can use arbitrary discretion in the design of projects. Flexibility should be exercised to better meet specific project goals or to work within defined constraints. Documentation needs to be provided to explain why the proposed design is an appropriate solution for the project, how it serves the needs of each transportation mode, how it is expected to perform in the future, and how it fits within available funding. This documentation is important to design reviewers, to management, and to the public.

The design process has formally recognized the concept of PBPD for a very long time through the Design Exception process. Where it is not practical to meet one of the Controlling Criteria due to various impacts and/or costs, a Design Exception is a formal approval process to evaluate and document the decisions. Design Exceptions will continue to be the method to document deviations from the Controlling Criteria during

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design. Deviation from other design criteria (non-Controlling Criteria) that do not require a Design Exceptions should also be evaluated and documented throughout project development as defined by the design process.

Design exceptions are a useful tool for employing practicality and flexibility in design decisions within the control of the department in a design-up approach. Implementation of PBPD should not necessitate changes in the department's existing procedures for requesting and approving design exceptions. As described in the FHWA *Mitigation Strategies for Design Exceptions*, an effective design exception process includes the following tasks:

- Determine the costs and impacts of meeting the design criteria
- Develop and evaluate multiple alternatives
- Evaluate risk, and
- Document, review, and approve exceptions

But, most importantly what is the purpose of the design exception? What impacts are there other than costs of bringing the features up to standard as specified under Design Criteria (e.g., impacts to other design features, ROW, environmental effects, preservation of historical feature, construction issues, social concerns, reduction of design life. . . .)? As part of the justification what are the benefits expected from the application of non-standard design values for all road users. The documentation of the value added is equally important as the identification of the non-conforming design element.

Flexibility is here now with the new Controlling Criteria. Based on research, design exceptions are no longer required on roadways with a design speed less than 50 mph for lane width, shoulder width, horizontal curve radius, superelevation rate and transition, maximum grade stopping sight distance and cross slope. While the geometric design element may not meet standards, the risk is such that an analysis and approval at the region level are sufficient (Road Design Manual 3.08.01E).

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Analysis

Analysis is a key component of PBPD. Emerging growth of analysis tools using relevant, objective data enables agencies to better evaluate projects within important program areas. Many projects include a stated or implied goal of improving mobility, reliability or safety; however, the roadway agency does not always have enough data to know whether a proposed project would accomplish that goal or whether a completed project has achieved its stated purpose. The use of appropriate analysis methods, such as the Highway Safety Manual (HSM) and the Highway Capacity Manual (HCM) and their associated tools, will allow agencies to effectively evaluate and compare the performance of various alternatives. As a result, the FHWA encourages agencies to plan and develop projects with a system performance mindset. This is not a new regulation, but rather a change in mindset that considers all roadway users, including pedestrians and bicyclists.

Evaluation of more than one design option is inherent in the performance-based approach. Doing so is necessary to compare the costs and expected performance of design alternatives. This has always been a preferred approach, but it is more essential in this regimen, especially considering diminishing resources and expanding needs. When comparing alternatives and their costs, a point of diminishing or no added return on investment often becomes clear, suggesting a logical limit of practicality and prudent expenditure. Furthermore, evaluating proposed spending against other potential uses of the same funds in another location or manner from the standpoint of performance improvement (e.g. crash reduction, vehicular delay) will be a useful thought exercise in seeking to optimize the overall return on investment statewide.

Safety Analysis

Traditional crash and roadway analysis methods mostly rely on subjective or limited quantitative measures of safety performance. This makes it difficult to calculate safety impacts alongside other criteria when planning projects. Data-driven safety analysis (DDSA) employs newer, evidence-based models that will provide MDOT with the means to quantify safety impacts like the way they do other impacts such as environmental effects, traffic operations and pavement life. These HSM analyses provide scientifically sound, data-driven approaches to identifying high-risk roadway features and executing the most beneficial projects with limited resources to achieve fewer fatal and serious injury crashes. This effort focuses on both predictive and systemic analyses—two types of data-driven approaches that can be implemented individually or in combination. For PBPD the predictive approach is used to quantify safety impacts.

Predictive analysis helps identify roadway sites with the greatest potential for improvement and quantify the expected safety performance of different project alternatives. Predictive approaches combine crash, roadway inventory, and traffic volume data to provide more reliable estimates of an existing or proposed roadway's expected safety performance. The results inform roadway safety management and project development decision-making. The data not only help MDOT make better decisions, but also inform the public as to what safety benefits they can expect from their investment.

HSM is an analytical tool which can be used to compare the expected crashes between different alternatives. HSM, like other analytical tools, should not normally be the sole basis of making decisions. It can, however, be a factor providing a quantified comparison of potential safety performance in terms of expected crashes.

When appropriate and when the situation does not exceed the capabilities of the software or research data set, HSM can be used to compare expected crashes between alternatives. Safety should always be an important consideration, however, that does not mean an HSM analysis cannot predict an increase in crashes on any proposed alternatives. The question becomes what the magnitude of the predicted crash increases is and what are the associated severities.

For example, it may be perfectly appropriate for a PBPD alternative to accept a modest increase in property damage (PDO) crashes if the offsetting benefits afforded by the alternative are commensurately high. It should be noted that an increase to the expected crashes predicted by HSM may be potentially mitigated with the application of appropriate safety countermeasures. These countermeasures should be factored into the HSM analysis.

Given the range of methodologies available, selecting an appropriate level of safety analysis from the HSM consistent within the context of the project development process and project type is a key component of implementing DDSA. Safety analysis methods should be used which will provide the necessary decision-making capability and can be performed with data typically available at the current phase of the project development process.

For what method and analysis tool(s) to use during project development safety analysis, design exceptions and alternative analysis refer to the Data Driven Safety Analysis Guidance.

For a description of the MDOT Safety Tools go to MDOT Safety Tools.

Insert language on mobility analysis

A Road Safety Audit (RSA) is a formal safety performance examination of an existing or future road or bridge project by an independent, multi-disciplinary RSA team. RSAs can be conducted at any stage of a project but are highly recommended prior to the Scope Verification meeting and include consideration for all users of the roadway to help achieve strategic safety goals. RSAs contribute to road safety by providing a fresh, unbiased assessment of the area or intersection to identify potential safety issues and solutions. Within MDOT there are many different project types with various funding mechanisms, at different levels of completion. The RSA Guidance Document provides guidance regarding the types of projects where RSAs are required and/or optional. RSAs are divided into two categories: in-service and design-service. Candidates for in-service RSAs include high-crash locations, and high-profile sites and locations with changed traffic characteristics. Warranting Conditions for RSAs are provided in the guidance document. For some projects while meeting the warranting conditions an RSA may not be required. A risk-based analysis may indicate that an independent, multi-disciplinary would be exempted for there are no overall safety concerns. For this situation, an RSA Exemption process is outlined in the RSA Guidance Document. This exemption however does not preclude a safety analysis as outlined in the Safety Analysis Guidelines from being done. The safety analysis in support of DDSA may yield a mitigation that is within the scope of work of the proposed project.

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Glossary

Data Driven Safety Analysis - The application of the latest Highway Safety Manual (HSM) evidence-based tools and approaches to safety analysis which provides reliable estimates of an existing or proposed roadway's expected safety performance. Data Driven Safety Analysis (DDSA) helps agencies quantify the safety impacts of transportation decisions, similar to the way agencies quantify: Traffic growth, Environmental impacts, Traffic operations, Pavement life and Construction costs.

Highway Capacity Manual - The Highway Capacity Manual (HCM) provides methods for quantifying highway capacity. In its current form, it serves as a fundamental reference on concepts, performance measures, and analysis techniques for evaluating the multimodal operation of streets, highways, freeways, and off-street pathways.

Highway Safety Manual - The Highway Safety Manual (HSM) provides practitioners with information and tools to consider safety when making decisions related to design and operation of roadways. The HSM assists practitioners in selecting countermeasures and prioritizing projects, comparing alternatives, and quantifying and predicting the safety performance of roadway elements considered in planning, design, construction, maintenance, and operation. Prior to the HSM, there was no widely accepted tool available to quantitatively assess the impact of infrastructure decisions on safety.

Performance-Based Design - Uses knowledge about the effects that roadway features have on actual performance (e.g. safety, quality of service, reliability) to help make design decisions. Its procedure emphasizes understanding the problem the project is addressing, the context and the audience (stakeholders and users) and developing a solution focused on addressing those problems and achieving defined goals.

Performance-Based Practical Design - The combination of Practical Design and Performance-Based Design encompasses the what (economic efficiency) and the how (performance-based, data-driven methodology), either of which is incomplete without the other. The Federal Highway Administration (FHWA) has defined Performance Based Practical Design (PBPD) as a decision-making approach that uses quantitative analyses to guide decision-making through the project development process. It is the combination of Practical Design and Performance-Based Design encompassing the what (economic efficiency) and the how (performance-based, data-driven methodology), either of which is incomplete without the other.

PBPD recognizes the limited financial resources within the department and the need to spend federal/state dollars appropriately and with a long-term, system-wide outlook. Every scoping and design decision should be made based on whether the proposed feature will address the project's stated desired goals as well as whether it represents a use of funds that makes good sense considering other needs on the system as a whole.

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Practical Design - Describes an approach to road building that makes the best use of financial resources to optimize the performance and physical condition of the overall transportation system and achieve long-term fiscal sustainability.

Road Safety Audit - A Road Safety Audit (RSA) is a formal safety performance examination of an existing or future road or bridge project by an independent, multi-disciplinary RSA team. RSAs can be conducted at any stage of a project but are highly recommended prior to the Scope Verification meeting and include consideration for all users of the roadway to help achieve strategic safety goals. RSAs contribute to road safety by providing a fresh, unbiased assessment of the area or intersection to identify potential safety issues and solutions. For more information see Guidance Document 10241.

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