



# Overview of Performance Based Practical Design

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**in cooperation with**  
**Kentucky Transportation Cabinet**  
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**Research Report**  
KTC-18-03/SPR17-546-1F

**Overview of Performance Based Practical Design**

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<b>16. Abstract</b> State transportation agencies (STAs) have increasingly turned to practical design and performance based practical design (PBPD) to inform project development and implementation — and to reduce project costs while optimizing systemwide benefits. PBPD is a design-up philosophy that encourages agencies to formulate projects to meet the purpose and need rather than adhering to ostensibly immutable design standards. This paper reviews practical design and PBPD concepts and initiatives and their application in a variety of contexts. It also summarizes best practices STAs can use to develop a PBPD program. As a holistic approach to project design, PBPD underscores context sensitive solutions that balance the needs of all roadway users, including motorists, bicyclists, and pedestrians. Common PBPD solutions include opting for low-cost enhancements, such as striping, signing, and rumble strips, as opposed to realignment; narrowing shoulder widths; redesigning projects to lower right-of-way costs; modifying interchange designs; and using design exceptions to build projects that fulfill project objectives. STAs committed to establishing robust PBPD programs will typically require 18 to 24 months to get a program off the ground. For an initiative to succeed, it is critical for executive leadership in an agency to advocate for PBPD; that agency staff learn about practical design and ongoing PBPD programs in other states; that a baseline performance evaluation of the tools, concepts, and resources currently used for project development be conducted; and that changes made to the project development process are thoroughly documented. The report closes with a series of recommended performance metrics the Kentucky Transportation Cabinet should consider adopting to improve its monitoring of critical bridge and roadway assets.			
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## Executive Summary

Financially beleaguered state transportation agencies (STAs) have become increasingly creative in their search for affordable, effective project design and development solutions. Since the Missouri Department of Transportation first introduced its practical design program in 2005, many STAs have embraced practical design or performance based practical design (PBPD) to transform their approaches to project development. PBPD is a design-up philosophy that emphasizes the importance of building projects to address the purpose and need rather than intransigently adhering to design criteria. Although design standards, either those articulated by individual agencies or those promulgated by national organizations (e.g., AASHTO's *A Policy on Geometric Design of Highways and Streets*), can be valuable, in some cases reflexively heeding them may result in designs that fail to satisfactorily meet a project's stated objective. Many agencies — now and in the past, — if they lacked the funds to incorporate all design standards into a project have subtracted elements piece by piece until a design is reached which fits within the available budget. PBPD rejects this approach to design because it does not foreground the purpose and need and produces only limited savings.

PBPD focuses on the use of fiscally responsible, context sensitive solutions to attain the most possible benefits for an entire transportation corridor or system. As such, the holistic philosophy underpinning PBPD stresses the importance of making the greatest number of improvements to maximize the impact to and performance of roadway systems rather than doing ambitious and expensive projects whose benefits are circumscribed and have limited effects on system performance. When applying a PBPD framework, it is important to establish metrics to assess project performance. Examples of performance metrics used by STAs include vehicle injury and fatal crash rates; pedestrian and bicycle injury and fatal crash rates; benefit-cost ratio; roadway capacity; peak hour traffic flows; congestion; freight movement; funding required for operations, maintenance, and rehabilitation; condition of bridge decks; and environmental quality. While STAs have devised many inventive design strategies under the PBPD rubric, several common ones include 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 or alignments to lessen right-of-way or environmental mitigation costs; and introducing active traffic management. It is also critical to involve stakeholders and communities impacted by projects early and consistently. A hallmark of PBPD is that it encourages agencies to be responsive to the needs and challenges of communities. Although a primary goal of PBPD is to reduce costs, it is imperative that design choices made during design and implementation do not shift cost burdens to another phase of operations (e.g., maintenance). STAs, including those in Missouri and Washington, have reported saving hundreds of millions of dollars by using practical design concepts, which they subsequently reinvested in other projects.

Guidance from the Federal Highway Administration and other researchers offer STAs practical tips for introducing PBPD. When exploring PBPD and whether it could potentially benefit an agency, it is important for agency personnel to grow their knowledge of practical design concepts by looking at existing publications and the experiences of other states. While it is critical to receive buy in from agency staff, it is especially important for leadership to endorse PBPD and foster an environment which is supportive of its use. Collaborating with external stakeholders, such as vendors, consultants, contractors, and local FHWA offices, can facilitate a smooth transition to a new project design and implementation philosophy. Before formally shifting to a PBPD framework, agencies must also perform a baseline assessment of the tools, processes, resources, and business practices which inform project development. Only with this information can an STA establish a proper trajectory for inaugurating a PBPD initiative and evaluating its performance. Agency leadership needs to clearly articulate the overarching goals of a PBPD program and how it will be enacted and administered. It is imperative to meticulously record and document changes in agency practice. Depending on the level of commitment, an agency will need between 18 and 24 months to bring a PBPD program online.

After examining PBPD initiatives throughout the United States, we investigated performance measures used by STAs with an eye toward developing recommendations for the Kentucky Transportation Cabinet (KYTC) to consider. The most useful performance measures are 1) quantifiable, letting agency personnel determine if their activities are helping the organization achieve its goals, and 2) applicable to the duties and responsibilities of a particular agency. Several states focus on design and construction activities, which have a demonstrable impact on safety. In light of this, the Cabinet should place a renewed emphasis on intersection and roadway departure crashes and monitoring sites with high numbers of vehicle crashes. The Cabinet will also benefit from using the historic traffic data it purchases to analyze performance trends and operational changes during peak periods compared to off-peak/free-flow periods. Leveraging this analysis, KYTC should develop performance indices able to identify high levels of congestion throughout the state. Most states monitor the condition of pavement and bridges, however, their programs for doing so vary in their level of sophistication. Missouri and Massachusetts, for example, have bridge repair programs that focus on deficiencies brought to light by performance monitoring. The Cabinet should consider developing a similar program to pinpoint assets in unacceptable condition. Information from such a program could be used to prioritize repairs. Lastly, KYTC should consider adopting a performance measure focused on projects delivered to letting on time and on budget. The Cabinet possesses all the data necessary to track these proposed performance metrics, and in doing so it will be able to improve the condition of the highway system in a cost-effective manner.

## Chapter 1 Review of Performance Based Practical Design and Its Recent Applications

### Introduction

In a period defined by fiscal austerity and diminishing budgets, state transportation agencies (STAs) have devised innovative strategies to deliver roadway projects that perform safely and efficiently. Hobbled by limited funding, agencies no longer have the option to focus on perfecting individual projects whose benefits will be experienced only by a small number of motorists. Rather, they must establish investment priorities and select projects that will provide systemwide benefits across transportation networks. In 2005, the Missouri Department of Transportation (MoDOT) introduced a practical design program to stretch its limited funding further. The goal of practical design is to build projects that satisfy criteria outlined in purpose and need statements, are attentive to local context, and improve short- and long-term system performance. Focusing on purpose and need rather than rigidly adhering to codified design standards (e.g., those in AASHTO's *A Policy on Geometric Design of Highways and Streets*) is what distinguishes practical design and performance based practical design (PBPD) from traditional approaches to project development.

In 2008, the Kentucky Transportation Cabinet (KYTC) launched its Practical Solutions initiative, which has many of the same goals as practical design. To understand how practical design has evolved over the past 10 years, this report defines and describes PBPD, an extension of practical design championed by the Federal Highway Administration (FHWA), reviews the how agencies have implemented practical design and PBPD, and identifies performance measures to inform the Cabinet's long-term investment decisions.

### Defining Performance Based Practical Design

Before practical design, the routine and accepted practices at STAs was to create design solutions that matched closely with agency design standards. If a solution proved too expensive, design elements were removed piece by piece until the project could be constructed with the available budget. But often this practice did not result in enough savings to reinvest elsewhere in the system. MoDOT's turn to practical design was at least partially motivated by agency management observing that rigorously adhering to standards resulted in overdesigned projects relative to the stated purpose and need, which tied up funds and limited the number of projects that could be completed. To avoid the pitfalls of overdesign, practical design and PBPD approaches encourage practitioners to begin a project by asking what a project must accomplish to fulfill the purpose and need — instead of asking how to meet standards.

Discursively, the dividing line between practical design and PBPD is tenuous. Many agencies with formal practical design programs have stated goals which very much seem to echo those of PBPD (see below). However, FHWA is keen to distinguish between them. Indeed, FHWA has published numerous guidance documents on PBPD which are at pains to highlight the differences between it and practical design. FHWA defines PBPD as a decision-making framework that helps agencies improve their management of transportation investments while fulfilling systemwide needs and performance priorities with limited resources<sup>1,2</sup>. More specifically, use of PBPD involves the application of a performance management framework to make decisions about how best to address purpose and need. FHWA argues this separates PBPD from practical design, which it critiques as being vulnerable to shortsightedness because it may prioritize short-term cost savings over other objectives (e.g., safety and operational performance, context sensitivity, lifecycle costs, long-range corridor goals, livability, sustainability). Agencies leveraging PBPD can use it to analyze project-level results within the context of overall system needs, goals, and performance. PBPD approaches balance the demands of all roadway users including pedestrians, motorists, and bicyclists. Performance analysis tools and qualitative assessments generate data that agencies can use to

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<sup>1</sup> Federal Highway Administration, "Start-Up Guide: Performance Based Practical Design," Publication No. FHWA-HIF-17-026, March 2017.

<sup>2</sup> "Performance Based Practical Design," Federal Highway Administration, accessed 11 October 2017, <https://www.fhwa.dot.gov/design/pbpd/>



develop projects that include only those features that fulfill short- and long-term performance goals. FHWA regards PBPD as a holistic way to approach decision making, one that scrutinizes system performance needs when solutions for individual projects are planned, scoped, and developed. In doing so, agencies using PBPD can potentially garner larger returns on investment by analyzing elements of a project scope relative to value, need, and urgency. Furthermore, PBPD attempts to balance project purpose and need with design — for all users and life cycle costs. A mature PBPD program will incorporate PBPD concepts into all decisions related to planning, programming, and project development. FHWA does not view PBPD as eliminating, modifying, or compromising existing design standards or regulatory requirements. While this may be true conceptually, design exceptions and design flexibility are integral to both practical design and PBPD.

Looking explicitly at practical design, Hillis argued that it is difficult to pin down a single definition<sup>3</sup>. As evidence of this, he presented a definition developed at a practitioner workshop, but which was not universally endorsed: “Practical design is the current state of practice for delivering highway improvements. It is a multi-disciplinary approach for delivering transportation projects that focuses on the well-being of the entire system, improves highway safety, manages assets in a cost-effective manner, and is sensitive to context and consumer needs.”<sup>4</sup> Rather than attempting a universal definition, Hillis found it more useful to outline general principles that practitioners commonly associated with practical design<sup>5</sup>:

- Maximizing available funding to achieve the best system outcomes possible
- Achieving the best possible balance between a project’s cost, quality, and timeliness of delivery
- Emphasizing adding value rather than only reducing cost
- Involving the local community and stakeholders throughout the program delivery process, including the identification of the purpose of and need for the project
- Determining purpose and need for a project by:
  - Focusing on doing as much as possible across the entire network to yield the greatest benefit
  - Reviewing the entire corridor, 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-measurable outcomes (i.e., community benefit and approval)

While this list identifies practical design’s emphasis on the entire system, it omits several critical elements that appear in most state guidance. Foremost is the principle of building a project to meet the purpose and need. This is the defining feature of many agencies’ practical design programs, as noted previously. Designing to purpose and need rather than to standards prevents overdesign and ensures projects are right-sized. Citing the importance of community involvement partially speaks to the importance of context but elides practical design’s emphasis on solutions that meet site-specific needs. Most agencies regard context sensitive solutions as congruent with and supportive of practical design because they facilitate solutions attuned to social and environmental settings. Exhaustively cataloguing the types of design strategies agencies have employed when applying practical solutions may be impossible in a set of high-level principles, but some appeal to them is warranted. One way to conceptualize practical design (and even PBPD) is as a decision-making framework that finds *savings around the edges* — sometimes quite literally — that when added together are immensely consequential for agency practice. Agencies have turned to a

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<sup>3</sup> Don Hillis. *Executive Strategies to Deliver Practical Design*. National Cooperative Highway Research Program Project 20-24, Task 102, July 2016.

<sup>4</sup> Hillis, p. 6.

<sup>5</sup> Hillis, p. 7.

common suite of design exceptions when adopting practical solutions — narrowing lane widths; narrowing shoulder width; minor geometric adjustments; the addition of rumble stripes, centerlines, and markers; and installing safety countermeasures. Identifying common sources of saving is essential and provides a useful reference point for agencies wishing to develop or expand their practical design programs. While the savings achieved on a single project may be somewhat modest (10 to 30 percent), if practical design or PBPD is applied consistently an STA can save hundreds of millions of dollars. Or in the case of MoDOT, over \$1 billion. This remainder of this chapter works through different state policies on practical design and PBPD and case studies where they have been applied; in doing so it progressively elaborates the contours of practical design and PBPD and the ways in which they can benefit STA practices.

### **Applications of Practical Design and PBPD at State Transportation Agencies**

#### *NCHRP Synthesis 443 — Practical Highway Design Solutions*

McGee’s wide-ranging survey of practical design initiatives at STAs established a baseline for understanding how practical design is used and its potential for helping cash-strapped agencies extend their limited resources further to achieve systemwide goals<sup>6</sup>. This summary of McGee’s synthesis is geared toward highlighting notable policies and practices introduced by states that were early adopters of practical design, including Missouri, Idaho, Kentucky, Kansas, Oregon, and Utah. It is not intended as an exhaustive review, although it will include references to original state guidance where appropriate.

MoDOT was the first transportation agency in the United States to develop and implement a practical design policy. Limited funding compelled the agency to look for new ways to stretch its scarce transportation dollars further. Equally, the policy grew out of agency management recognizing that many projects which adhered strictly to design standards were overdesigned when assessed against the purpose and need. MoDOT’s practical design philosophy is straightforward — design projects that correct deficiencies while fulfilling the purpose and need of the corridor. The current practical design implementation manual emphasizes aligning the project scope with the project purpose and creating designs that are sensitive to project context<sup>7</sup>. Getting the most value for the least amount of money while not pushing costs onto maintenance activities is MoDOT’s primary goal. Three ground rules guide MoDOT’s approach to practical design: 1) safety will never be compromised; all facilities will be safer upon project completion; 2) developing solutions is a collaborative endeavor that brings together multidisciplinary stakeholders; and 3) the design speed must equal the posted speed (i.e., a road is not designed for a speed higher than what is posted). While practical design can be used on any type of project, McGee observed that its use is less common on higher order facilities because of their higher design speeds. MoDOT authorizes district offices to approve design exceptions, which are sometimes necessary when, for example, lane widths are narrower than stipulated by AASHTO criteria or design standards. Conversations with MoDOT officials suggested that practical design is most effective when deployed at the scoping level. The savings from using practical design are returned to district offices, which lets them complete other projects. From 2005 to 2009, MoDOT saved approximately \$1.2 billion using practical design. MoDOT’s practical design implementation manual contains instructions for applying practical design to various projects and facilities, such as at-grade intersections, shoulder width, median, width, roadside ditches, horizontal and vertical alignments, pavement, structures and hydraulics, and others. Each section includes primary guidance and in-depth discussions that clarify how projects are to be executed.

After witnessing the success of MoDOT’s rollout of practical design, the Idaho Transportation Department (ITD) introduced its own practical design initiative. Many of its goals overlap with those specified by MoDOT. According to IDT, a key foundation of practical design is correctly defining project scopes to

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<sup>6</sup> Hugh W. McGee, Sr., *Practical Highway Design Solutions: A Synthesis of Highway Practice*, NCHRP Synthesis 443, 2013.

<sup>7</sup> Missouri Department of Transportation (MoDOT), *Practical Design*, 2006.

ensure they align with purpose and need statements. Project designs must harmonize with the surrounding context. And like MoDOT, ITD emphasizes the importance of not viewing practical design to shift cost burdens to maintenance. The agency contends practical design is used most efficiently if it is introduced during the planning stage. McGee reported that many ITD district staff were receptive to practical design because of the state's challenging terrain, which already required numerous design exceptions. ITD's guidance document reviews design criteria to be used during transportation planning as well as guidelines for several roadway design elements. The section on primary guidance, in addition to reaffirming the importance of building to the purpose and need statement, affirms that the design speed is to match the posted speed. The agency does not regard congestion as something that must be eliminated — in some cases, modest levels of congestion can support more efficient use of roads by encouraging the use of carpooling, transit, or other alternatives. Specifically, all routes in rural areas should be able to accommodate 20-year peak hour traffic at LOS D and off-peak traffic at LOS C. The guidance document also describes the application of practical design to numerous facility types and design activities, such as lane and shoulder width, horizontal and vertical alignments, structures, bicycle and pedestrian facilities, and the right of way.

In addition to Kentucky and Oregon (see below), McGee also touches on practical design efforts at the Kansas and Utah Departments of Transportation. The Kansas Department of Transportation (KDOT) has established a Practical Improvements program. The agency defines practical improvement as “the overarching philosophy which guides our decisions that affect project cost and scope in order to stretch our transportation improvement dollars further while still maintaining a safe and efficient highway system.”<sup>8</sup> Like other agencies, KDOT underscores the importance of staying within budget and developing careful, well-honed scopes. Its guidance sanctions development of alternative scopes if the initial scope fails to address specific needs or over-addresses them. The purpose of creating alternative scopes is to help KDOT select the option that most effectively balances cost, operations, environmental concerns, stakeholder input, and safety. Design exceptions are sometimes necessary when selecting an alternative scope that includes design elements falling outside of normally accepted design criteria. KDOT also maintains a performance measures website<sup>9</sup> that summarizes in an accessible format data on safety, bridges, pavement, and other facets of the transportation system (Figure 1). Other STAs and MPOs use similar performance dashboards to communicate essential information to the public about system performance, which lets citizens hold them accountable for their of taxpayer funds.

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<sup>8</sup> McGee, p. 21.

<sup>9</sup> “Performance Measures,” Kansas Department of Transportation, accessed 11 October 2017 <https://kdotapp.ksdot.org/perfmeasures/>.

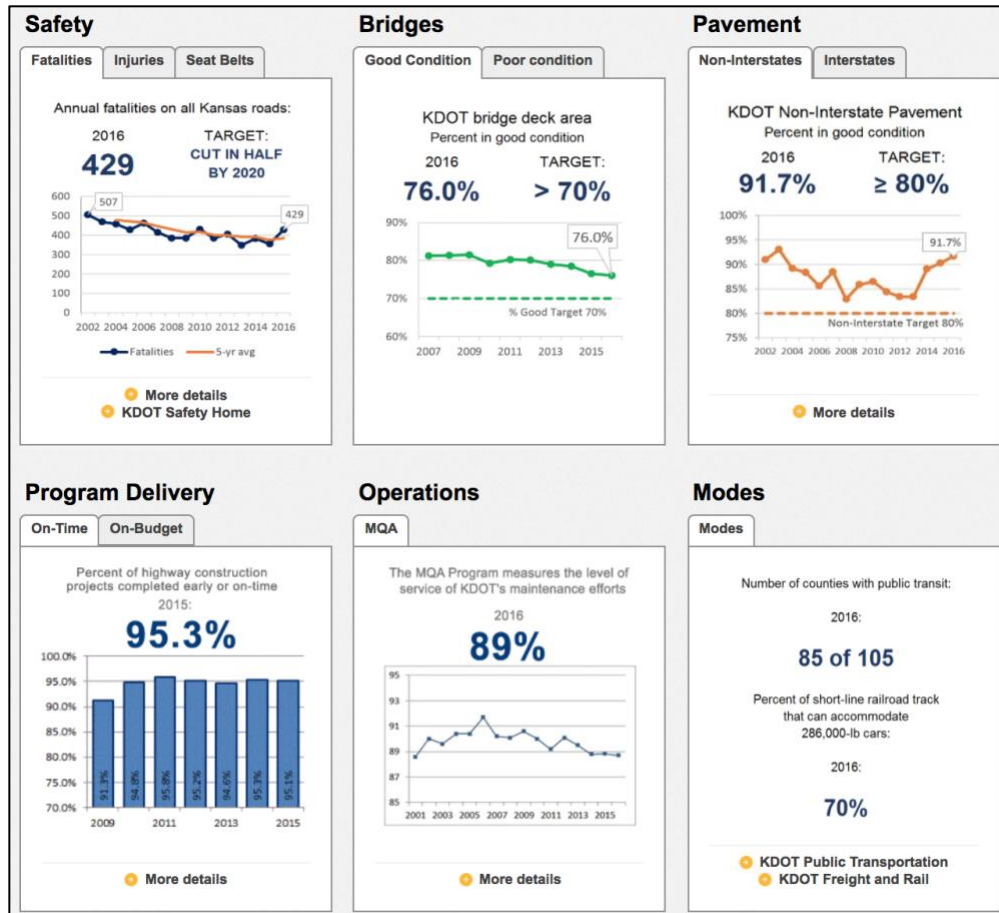


Figure 1 KDOT Performance Measures Website

The Utah Department of Transportation’s (UDOT) reasons for adopting practical design mirrored the rationales offered by other agencies<sup>10</sup>. Echoing MoDOT, UDOT states the goal of its practical design program is to maximize improvements to roadway systems rather than privileging a small number of projects whose benefits have limited reach. But unlike some other agencies, which have commented that practical design is most effective when used during planning or scoping, UDOT applies practical design during all stages for project development — from initial planning through final construction. Building to the project’s objective statement (i.e., purpose and need) is an integral part of UDOT’s approach to practical design, and this appears in two of the agency’s three goals for practical design: 1) optimize the whole transportation system; 2) meet the goals of the objective statement identified for each project; and 3) design the most efficient method (cost and function) to achieve the objective statement. Under practical design, working toward systemwide optimization (Goal 1) requires helping project teams to understand how their project fits within the roadway system and its alignment with corridor priorities, communicating knowledge about the system and corridor to the project team, prioritizing analysis (e.g., safety analysis) during the development of alternatives, and devising solutions that optimize the entire highway system. Achieving Goal 2 requires that designers develop solutions that meet the needs outlined in the objective statement; using exceptions, waivers, and deviations wherever necessary to meet the project objective; fulfilling stakeholder requests that accord with the project objective; and developing designs that most efficiently satisfy the objective statement and corridor priorities. The approach to meeting Goal 3 under UDOT’s

<sup>10</sup> Utah Department of Transportation, Practical Design Guide: Planning and Designing Practical Transportation Solutions for Utah, 2011.



practical design framework includes maximizing cost savings while fulfilling the project objective; evaluating life cycle costs; focusing on building up (i.e., design-up) from existing conditions to meet the project objective; scrutinizing how much value is added by improvements; and working to save project resources so they can be applied to projects elsewhere. McGee observed that UDOT regards practical design as combining context sensitive solutions and value engineering. Nevertheless, UDOT's practical design guidance distinguishes between the two, defining value engineering as a method to determine the most cost-effective way to achieve proposed improvements focused on maximizing project improvements, and as a tool for practical design. Conversely, practical design is about identifying the most cost-effective way to satisfy the objective statement while maximizing the improvements made to Utah's entire transportation system.

#### *Washington Department of Transportation<sup>11</sup>*

Beginning in the 1990s the Washington Department of Transportation (WSDOT) started to eliminate design elements that had been required to bring highway features up to standards. However, initial efforts to use this practical approach to design were spotty, and often solutions were not consequential for the entire transportation system. Additional guidance was issued in the early 2000s related to the evaluation of designs and to the need to evaluate and mitigate design tradeoffs in specific contexts; however, additional approvals were required for atypical designs that did not conform with standard practices. Thus, the agency's design manual was treated as, in its words, a formulaic cookbook preoccupied with a standards-based approach to project design with little attention paid to how project designs should account for factors such as land use context, performance outcomes, and modal integration. Attempting to address this situation, the WSDOT Strategic Plan for 2014-2017 included Reform V, which called for the implementation of practical design to increase the flexibility of the agency's project development process. WSDOT regards practical design as "[offering] flexibility without sacrificing operations, performance, community livability, economic development, and environmental stewardship."<sup>12</sup> Its goal is to leverage practical design concepts to design and develop transportation projects that address essential needs — not every need.

As part of its turn toward practical design, WSDOT has adopted a least cost planning methodology to identify low cost, high benefit transportation solutions. The methodology prioritizes engagement with community stakeholders, and is a multi-step process that includes the following activities: garnering early support from communities through collaboration and setting project goals consistent with community values; developing a problem statement with an unambiguous purpose and need; identifying performance measures and indicators; using stakeholder input to evaluate alternatives based on goals and other project criteria; and determining which alternative offers the best return on investment. WSDOT uses a variety of performance measures to evaluate alternatives. These include:

- Safety
- Crashes
- Operational performance
- A community's sense of place, safety, and public health
- Environmental factors (e.g., air quality, open space, greenhouse gas emissions)
- Opportunities for affordable housing and mixed-income communities
- Land use and growth management plans established by local jurisdictions
- Walkability, accessibility, availability of multiple transportation choices

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<sup>11</sup> Washington State Department of Transportation (WSDOT), *Practical Planning and Design Leads to Low Cost Transportation Solutions*, June 2015.

<sup>12</sup> WSDOT, 3.

Working to implement practical design reforms, in 2013 WSDOT evaluated its design manual and standards to identify areas for revision. A first step in this process was revising outdated design standards to conform with current AASHTO criteria. Because the outdated standards were stricter than those AASHTO prescribes, compliance drove up project costs. Design guidance changes were made in several areas, including intersection control type analysis, intersection junction angles and lane alignment, highway sight distance, intersection and design vehicle, sustainable highway safety, and design and maintenance coordination. The revised 2015 Design Manual affords designers and engineers greater flexibility and underscores the importance of factoring in context, modal performance, and increasing community engagement during project development. Several other updates were made to the 2015 Design Manual as well. These include the removal of design matrices that had been used to facilitate selection of design elements during construction or reconstruction (as they can result in overdesigned projects), the addition of performance-based decision making design policy to ensure practical design is systematically integrated throughout project development, the inclusion of a chapter on design control, development of a context classification system to support quantitative analysis of land use characteristics and transportation environments to select design controls, and adding a *basis of design* tool to guide the selection of design elements and their dimensions. WSDOT has also added several new tools to conduct safety performance analysis such as AASHTO's *Highway Safety Manual*, SafetyAnalyst, Interactive highway Safety Design Model (IHSDM), Collision Analysis Data Report, Interchange Safety Analysis Tool enhanced (ISATe), and *Highway Safety Manual* spreadsheets.

In 2015, WSDOT reviewed a sample of 10 projects (conducted during the second half of 2014) that had incorporated practical design concepts during the early stages of project development. Cost savings (based on pre-construction estimate) ranged from 14 to 64 percent, with an average savings of 40 percent. Total cost reductions attributable to the use of practical design was \$215 million. Previous projects completed by WSDOT using practical design exhibited comparable savings as well. For example, the cost of SR 167 completion fell from \$1.5 billion to \$790 million by modifying interchanges and by reducing the scope of the full build out in some locations (from two lanes to one). The cost of SR 509 completion dropped from \$1.3 billion to \$750 million by eliminating one lane in each direction along a segment. By reducing the design speed to 60 miles per hour, using 11-foot lanes, and obtaining design exceptions for shoulder widths, the agency saved approximately \$600 million dollars on a project that widened Interstate 405 between Renton and Lynnwood. Considerable savings have been realized on smaller projects also. A full discussion of these is beyond the scope of this report<sup>13</sup>; it is worth highlighting some of the practical design solutions used on them:

- Construction of roundabouts instead of grade-separated intersections
- Adjusting project staging to increase efficiency
- Modification of interchange designs
- Opting for low-cost enhancements (e.g., striping, signing, rumble strips) instead of realignment
- Redesigning projects to reduce right-of-way costs
- Changing repair methods following value engineering studies
- Use of alternative shoulder designs and making clear zone improvements
- Adjusting design or alignments to reduce environmental mitigation costs

#### *Indiana*<sup>14</sup>

The Indiana Department of Transportation (INDOT) established its *Open Roads* program to inject practical design principles into the agency's everyday practices. *Open Roads* is an agency-wide initiative that reaches

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<sup>13</sup> See WSDOT, pp. 11-14.

<sup>14</sup> Indiana Department of Transportation (INDOT), *Open Roads: Practical Design for Transportation Project Delivery*, May 2014.

beyond design. The core principles of *Open Roads* inform INDOT's project delivery model and influence the planning, scoping, design, construction, operation, and maintenance of projects. Additionally, the program stresses the importance of collaboration, empowerment, and innovation to build a transportation system that benefits all residents of Indiana. And like many other STAs, INDOT views *Open Roads* as a vehicle to help the agency move beyond an inflexible, standards-based approach to design. Rather than perfecting individual projects by designing them to achieve the safest and most desirable condition, *Open Roads* prizes solutions that improve a corridor's overall condition and function. Adopting this framework, the agency believes, will reduce project life cycle costs, freeing up money that can be reinvested elsewhere in the system to fund other projects found in the state transportation improvement plan. The success of *Open Roads*, according to INDOT, hinges on the use of decisive and clear purpose and need statements to guide project development, a clear process for approving and documenting the reasoning underlying key decisions, and the use of sound engineering judgement when analyzing the consequences of decisions and design tradeoffs.

INDOT self-consciously modeled *Open Roads* on practical design initiatives launched in other states — most notably, Missouri. Four principles serve as cornerstones of the *Open Roads* program, including sound engineering judgment, adoption of a design-up philosophy, a commitment to getting the scope right, and a safer system focus. With respect to engineering judgment, INDOT holds that it is critical for designs to rest upon sound engineering judgment; however, it is imperative for common sense, context awareness and sensitivity, and innovation to influence design decisions as well. Sticking with traditional design standards forecloses the possibility of selecting more practical alternatives better suited to project and programmatic goals. Other states, as well as the FHWA, speak about the importance of a design-up philosophy. It contrasts with the typical approach taken by designers, which entails beginning with a desired condition and then removing items to meet scope and budget. INDOT understands design-up as beginning with a close assessment of a facility's baseline condition. Once that is evaluated, designers should design up from that point to meet a project's purpose and need (think of it as a process of assembly rather than deconstruction). The result, ideally, is safe, practical, and economical roads and bridges. The design-up philosophy is also premised on the idea that investing more than is required to fulfill the purpose and need is wasteful; those funds could and should be directed to other projects. The third tenet of *Open Roads* is getting the scope right. All projects must have a targeted, honed, and well-documented purpose and need statement that describes what problem a project is intended to solve and the improvements necessary to enhance the corridor or network. Any features that do not directly support the purpose and need statement should be removed. Doing so prevents scope creep. The final principle of *Open Roads* is a safer system focus. Underlining the importance of a system-oriented perspective is critical for developing projects that optimize the condition and performance of an entire corridor. All projects must achieve levels of safety equal to or higher than the existing condition, but adopting a holistic focus can facilitate the use of targeted investments whose benefits are realized throughout a transportation network. While not named as a formal principle, INDOT highlights the importance of “early, deep, and consistent stakeholder engagement,” which democratizes the process of project development, and the importance of multi-disciplinary stakeholders working together to devise high-performing solutions. Promoting dialogue between stakeholders and creating an environment in which all participants mutually respect one another is helpful for incisively analyzing the effects decisions have on the condition and function of transportation networks.

Starting with projects let after 1 January 2015, INDOT mandated that project review teams (helmed by agency project managers) review project designs and supporting documentation to determine where additional efficiencies could be incorporated into designs that would result in cost savings of at least 10 percent. The *Open Roads* plan calls for the establishment of six multi-disciplinary project review teams, one for each of INDOT's districts. It recommends including representatives knowledgeable in the following topics: project management, project scoping, design, bridges and hydraulics, pavement, traffic, construction, maintenance, Central Office Design Reviewer, and consultants. If necessary, project teams have the authority to request assistance from other INDOT offices and personnel. The agency believes this

open and collaborative method of evaluating projects fosters development of a shared culture (see INDOT 2014 for a complete review of the project review process). Alongside project review teams, INDOT is also forming policy advisory teams whose goal is to examine the agency's current policies and identify ways to improve them and other processes to streamline decision making and hasten project delivery.

### *Ohio*

The Ohio Department of Transportation (Ohio DOT) is currently developing formalized guidance for PBPD, although it is also working to make greater use of practical design concepts throughout project development. The agency regards PBPD as a planning and design philosophy that will guide decision-making to “ensure it is making the best possible investments in [Ohio’s] transportation system *as a whole*. Entailed by this definition is the goal of “making informed, risk-based decision that balance the realities of fiscal constraints, right of-way, environment, capacity, and stakeholder input without sacrificing safety.”<sup>15</sup> As such, projects must prioritize safety; it is critical to bear in mind that no project is of greater importance than the entire system. Executing a larger number of good projects thus benefits the system significantly more than completing one great project. In embracing practical design, Ohio DOT is shifting its focus toward making affordable improvements throughout the state’s transportation system rather than costly improvements that will have negligible impact across the system. Several justifications have been offered for the shift toward PBPD that are also consistent with Ohio DOT’s organizational philosophy, such as limited funding and resources limiting the number of projects than can be done; aging infrastructure; environmental constraints; and new tools and technologies available to evaluate current and future performance. The agency is careful to point out that PBPD does not eliminate, modify, or compromise existing design standards and regulatory requirements. Leveraging performance analysis lets agency staff make more informed decisions about what will benefit the project and system. And in scrutinizing each component of a project’s scope relative to value, need, and urgency, the agency can expect a higher return on its investment.

The *Highway Safety Manual* is a cornerstone of PBPD in Ohio (like many other states), as it is imperative to quantify and comprehend the safety implications of various design solutions. Historically, Ohio DOT and other STAs have viewed meeting design standards as a proxy measure of a design’s safety. But this may not be the case; using the *Highway Safety Manual* lets engineers adjudicate the most appropriate and safe design<sup>16</sup>. Like other state agencies, Ohio DOT emphasizes that PBPD is a design-up approach that uses engineering judgment to build up improvements from existing conditions to satisfy project and system objectives. This does not equate to abandoning design standards, but it does involve being more judicious and pragmatic in their use. Not only can designs that inflexibly adhere to standards be very expensive, they may not solve the problem(s) described in purpose and need statements. When individual projects are scoped and developed, Ohio DOT focuses on the project itself and its placement and relationship to the overall system as well as the performance needs and objectives that have been laid out for the system. Several guiding principles underpin the agency’s PBPD framework, including the use of the designs consistent with corridor context; optimization of mobility, operations, and modes; bringing the public into discussions about project development; increasing return on investment; and recognizing that no single project is more important than the system.

### *Oregon*<sup>17</sup>

The Oregon Department of Transportation’s (ODOT) *Highway Design Manual* contains a section on practical design. Prior to the integration of practical design concepts into the manual, design guidance was

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<sup>15</sup> Dave Slatzer, “Performance Based Practical Design at Ohio DOT,” OTEC Conference Presentation, 2015.

<sup>16</sup> Katherine DeStefano, “Performance Based Practical Design,” Ohio Department of Transportation District 08 LPA Day, 2016.

<sup>17</sup> Oregon Department of Transportation “Design Standard Policies and Processes,” in *2012 Highway Design Manual*, pp. 1-1–1-35.



built around context sensitive design practices, using FHWA’s “Flexibility in Highway Design” and AASHTO’s “A Guide for Achieving Flexibility in Highway Design” as key references. ODOT views the use of practical design as a natural progression, building on its stated commitments to context sensitive solutions. The agency defines practical design as a philosophy and strategy for developing project scopes that are tailored to a purpose and need. It also regards practical design as a systematic approach to roadway network improvement geared toward optimizing limited funding to produce the greatest benefits for the system. ODOT has three major goals for practical design: 1) direct funding toward activities and projects that optimize the entire system; 2) develop solutions that address the purpose and need identified for each project; and 3) design projects that improve the entire system, address changing needs, and maintain current functionality by at least meeting goals outlined in project purpose and need statements.

Along with its three major goals, ODOT has outlined five values that inform how it approaches practical design. The first is *safety*. Under no circumstance is system safety to be compromised — all projects should use sound engineering judgment and either make a facility safer or maintain existing level of safety. Next, is *corridor context*. ODOT advocates a corridor approach for developing or assessing design criteria. Once this approach has been identified and agreed to, it should be used along an entire corridor. Furthermore, roadways must be compatible with community values, account for current and future land use, align with the corridor’s intended use, and mesh with the natural and built environments. Thirdly, practical design helps *optimize the system*. In addition to optimizing safety, mobility, and financial investment, this value encompasses the implementation of an asset management approach for managing pavements, bridges, and other roadway features. The fourth value is *public support*. ODOT regards public involvement as central to practical design. Engaging and collaborating with the public assists the agency in developing solutions that are endorsed by communities while being attentive to the needs of motorists, pedestrians, bicyclists, and transit users. The final value is *efficient cost*. Like most other transportation agencies in the United States, ODOT’s funding is limited. Therefore, it must stretch available funding by building projects that address only the stated purpose and need and by reallocating unused monies to other projects which may have a lower priority ranking.

## Case Studies

### *Metropolitan Planning Organizations (MPOs)*<sup>18</sup>









FHWA has documented MPO experiences with PBPD and, more recently Performance Based Planning and Programming (PBPP). What differentiates PBPP from PBPD is its commitment to a broader strategy that considers how performance-based initiatives can apply to strategic planning, programming, design, and the implementation and evaluation of projects throughout an entire region (or area of interest). While PBPD has a system-oriented focus, PBPP aims to identify goals and objectives at the regional level, which are then used to guide a region’s transportation plan and program. Essentially, PBPP is a scaled-up iteration of PBPD, although rather than beginning decision making at the project level to figure out how the purpose and need can be met efficiently while contributing to overall system objectives, it begins with a top-down view, articulating broad systemwide goals that will then help agencies plan and design individual projects so they are compatible with regional or area objectives. The approaches complement one another.

One of the most challenging aspects of PBPP is selecting appropriate performance measures to make planning and design decisions and track the long-term effectiveness of different projects. FHWA looked at the performance measures contained in several local and regional transportation plans. These metrics provide insights other agencies can draw on when choosing performance measures. The 2050 Regional Transportation Plan released by the San Diego Association of Governments includes several measures to evaluate the performance of individual projects and the entire transportation system — vehicle injury and

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<sup>18</sup> Federal Highway Administration, “Transportation Systems Management and Operations and Performance Based Practical Design: Case Study 4 — Demonstrating Performance Based Practical Design through Regional Performance Based Planning,” Publication No. FHWA-HOP-16-040, August 2016.

fatal crash rates, pedestrian and bicycle injury and fatal crash rates, percentage of funding spent on maintenance and rehabilitation, and percentage of funding directed toward operations. The Metropolitan Transportation Commission (San Francisco Bay area) assesses proposed transportation projects using benefit-cost analysis to determine which should be included in its long-range transportation plan. Along with the benefit-cost ratio, additional performance measures are used to evaluate projects, including travel time in millions of hours, number of crashes, and tons of pollutants emitted. The Delaware Valley Regional Planning Commission (DVRPC; MPO for greater Philadelphia) developed performance indicators for not just transportation, but also for economic, community, and environmental goals. Figure 2 illustrates the performance measures for transportation and the dashboard format used to summarize performance trends. Key performance measures include vehicle crashes and fatalities, level of congestion, number of drivers, and condition and maintenance of bridges and roads, among others.

What We Track	How is the DVRPC Region Performing?	Trend
<b>TR 1:</b> Have vehicle crashes and fatalities declined?	Between 2001 and 2005, the DVRPC region experienced an 18% decrease in fatalities per million VMT and less than 1% decrease in all crashes per million VMT. However, the overall number of crashes rose by 4.6% during this same time period.	
<b>TR 2:</b> Is congestion getting worse?	Congestion appears to be stable – neither improving nor worsening, though VMT has increased.	
<b>TR 3:</b> Is transit ridership increasing?	While transit ridership has experienced some fluctuation, it has increased in the last 5 years.	
<b>TR 4:</b> Has the number of deficient bridges in need of rehabilitation or replacement decreased?	The number of bridges identified as structurally deficient in the DVRPC region has remained steady, but remains twice as high as the acceptable level set by FHWA in its current strategic plan.	
<b>TR 5:</b> Are roads better maintained?	The region saw a slight increase in road miles considered to be deficient, mostly due to NJDOT's stricter standards.	
<b>TR 6:</b> Are fewer people driving to work alone?	The number of people driving to work by themselves continues to increase and is now 73% of all commuters.	
<b>TR 7:</b> Are people driving less?	There are more cars and more drivers driving more miles every year in the region. The region appears to be more auto-dependent.	
<b>TR 8:</b> Are DVRPC's TIP investments in keeping with the LRP goals?	Approximately 97% of the mapped 2007-2010 TIP project funding supports the Long Range Plan and its stated goals.	

**Figure 2** Performance Measures Dashboard for DVRPC

*Interstate 94 Expansion — Milwaukee, Wisconsin<sup>19</sup>*

Nearing the end of its useful life, the Wisconsin Department of Transportation (WisDOT) sought ways to expand portions of the Interstate 94 east-west corridor in Milwaukee County. The project’s goals were to select an alternative that improved safety and lowered crash rates, provided an acceptable level of service through 2040, continued to serve as a critical transportation link, and replaced deteriorating pavement. Early analysis ruled out rebuilding the six-lane freeway because at least eight lanes would be needed to reduce congestion and accommodate future traffic growth. However, adding two lanes was challenging because WisDOT could not acquire additional right of way due to the presence of nearby cemeteries. As such, the agency examined three alternatives: 1) an at-grade design that reduced lane widths to 11 feet, incorporated

<sup>19</sup> Federal Highway Administration, “Transportation Systems Management and Operations and Performance Based Practical Design: Case Study 2 — Demonstrating Performance-Based Practical Design through Urban Freeway Reconstruction,” Publication No. FHWA-HOP-16-034, August 2016.

variable shoulder widths, and had no interchange with nearby Hawley Road; 2) the same as Alternative 1, but with a half interchange at Hawley Road; and 3) a double deck design with four lanes in each direction and two auxiliary lanes connecting ramps to Hawley Road. WisDOT used several analysis tools to model the anticipated performance of each alternative, including the Enhanced Interchange Safety Analysis Tool (ISATe), Highway Capacity Software (HCS), Synchro, and Paramics. Analysis revealed that Alternative 2 would provide acceptable safety and level of service outcomes while carrying a price tag roughly one-third that of the double deck alternative (\$125 million versus \$295-\$345 million). The design, however, required design exceptions for segments with 11-foot travel lanes and narrow shoulders. A design exception for inadequate sight distance was necessary as well.

#### *Active Traffic Management — New Jersey<sup>20</sup>*

Active traffic management (ATM) strategies include adaptive ramp metering, dynamic lane assignment, dynamic speed limits, dynamic shoulder lanes, dynamic junction control, and queue warnings. A study for the New Jersey Department of Transportation (NJDOT) applied a PBPD framework to analyze ATM strategies. The study began with a feasibility and screening process to gauge if ATM strategies would align with the agency's regional and statewide goals and objectives. Road segments anticipated to benefit the most from the adoption of ATM strategies were identified at the outset of the study. Segments were then screened with these performance considerations in mind: existing transportation systems management and operations, intelligent transportation systems, safety, recurring congestion and bottlenecks, route purpose (e.g., major freight corridor), venues and areas served, and evacuation routes. Once the initial screening was complete, more data-intensive forms of analysis were used to determine appropriate solutions. This included the use of benefit-cost analysis to evaluate the following ATM options: full gantry approach, hybrid approach, and shoulder use considerations (with a best and worst case scenario defined and analyzed for dynamic shoulder lanes). Benefits were measured in terms of how significant a reduction in crashes and congestion would result from the use of ATMs. Freight and constructability were also factored into the assessment — priority highway corridors received emphasis while constructability was scrutinized because of the significant uncertainty associated with dynamic shoulder lanes. Following analysis, the study recommended implementing the following ATM projects — adoption of dynamic speed limits, lane assignments, and queue warnings on Interstate 287, Interstate 80, or both, leveraging a hybrid approach. The study also put forward a recommended gantry layout (full span on one direction of the roadway) for New Jersey that incorporated dynamic lane assignment, dynamic speed limits, and queue warning strategies.

#### *Interstate 95 — Near Miami, Florida*

A 21-mile stretch of Interstate 95 with four general purpose lanes and one HOV lane regularly suffered from gridlocked conditions that reduced travel speeds, lead to significant variability in trip times, and limited throughput during peak periods. The Florida Department of Transportation and Miami-Dade Metropolitan Transportation Planning Organization collaborated to investigate this problem and identify strategies to improve traffic flow. In their search for a solution, the agencies prioritized maximizing throughput, increasing travel time reliability, and encouraging the use of trip-reducing transportation modes. Six alternative designs were developed, with performance measures for each analyzed; the performance measures included the creation of multilevel detailed traffic models, assessment of optimum toll levels, estimates of traffic volumes by time of day and direction of travel, estimates of potential revenue, and assessments of operational benefits. Scrutinizing performance measures for each alternative let the agencies verify their decision was grounded in a sound performance management framework. Alternatives ranged in scope and ambition, from minor geometric adjustments to the construction of elevated managed lanes. They were ranked based on overall operational variability, capacity impacts, how much congestion

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<sup>20</sup> Federal Highway Administration, "Transportation Systems Management and Operations and Performance Based Practical Design: Case Study 5 — Demonstrating Performance Based Practical Design through Analysis of Active Traffic Management," Publication No. FHWA-HOP-16-087, August 2016.

relief would be realized, demand management ability, revenue potential, capital costs, and the affordability of toll rates. Ultimately, the agencies selected an alternative that placed all lanes on the existing grade. Lanes were narrowed to 11 feet and shoulders were narrowed as well — which required a design exception.

#### *Arizona SR 264<sup>21</sup>*

Located in Navajo County in northwestern Arizona, SR 264 was an undivided highway with 12-foot travel lanes in each direction and shoulders one foot wide. To reduce the high rate of run-off-road crashes, the Arizona Department of Transportation (ADOT) adopted a PBPD framework to analyze the potential effectiveness of the following alternative design strategies: 1) widening the existing one-foot shoulders to five feet, adding centerline and shoulder rumble stripes, flattening side slopes, guardrail installation, extension of pavement structures, and installing delineators and recessed pavement markers; 2) widening the existing one-foot shoulders to eight feet and installing the other features listed in Alternative 1; and 3) bringing the cross slope into compliance with AASHTO's current recommendation for minimum superelevation rates. Traffic safety analysis found that Alternative 1 would reduce the number of crashes by 16% over the 2016–2036 period, Alternative 2 would lower the number of crashes over this period by 21%, while Alternative 3 would yield only a 0.2% reduction in crashes. A benefit-cost analysis supplemented the safety evaluation. It indicated a benefit-cost ratio of 2.30 for Alternative 1 and 1.90 for Alternative 2 — the benefit-cost ratio for Alternative 3 was less than one, providing evidence against adjusting the superelevation. ADOT would have preferred Alternative 2 because of the added safety benefits; however, funding constraints made Alternative 1 the only practicable option. Because funding was not available to complete the entire project at one time, it was divided into two segments, with the segment expected to have a higher reduction in crashes receiving priority.

#### *Kansas Highway 177<sup>22</sup>*

Having a budget of just \$25 million and with total reconstruction estimated to cost \$67 million, the Kansas Department of Transportation (KDOT) leveraged PBPD to modernize Kansas Highway 177. The agency leveraged data analysis, stakeholder discussions, and an evaluation of alternative design concepts, all while being guided by the principal of *design to budget*. Early public involvement was critical for understanding the concerns and priorities of residents and developing targeted and effective solutions. Traffic and safety analysis (facilitated by the HCM and TWOPAS, a computer simulation program used to model two-lane highways) indicated that the level of service for the design year would be at LOS B or better along the entire corridor, which ruled out the use of costly and unnecessary upgrades such as the addition of passing lanes. Since level of service and traffic operations were not a concern, KDOT focused its energies on improving roadway safety. The agency divided the corridor into nine segments to devise alternatives for narrow increments. In doing so, engineers selected alternatives to align with the needs of each segment. The recommended improvements included reconstructing approximately five miles of the existing alignment, widening the typical section along the entire corridor from 26 feet to 40 feet, retaining existing pavement in locations outside of areas slated for reconstruction, bridge replacement, and bridge extension. The new design paired 12-foot lanes with 8-foot composite shoulders, whereas the existing cross sections consisted of 13-foot lanes with no shoulders.

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<sup>21</sup> Federal Highway Administration, “Case Study: Arizona 264 Burnside Junction to Summit – Safety Improvement Evaluation,” Publication No. FHWA-HIF-15-04, 2015.

<sup>22</sup> Federal Highway Administration, “Case Study: K-177 Modernization Project,” Publication No. FHWA-HIF-14-018, 2014.



## Implementation of PBPD and Practical Design

Because of the newness of practical design and PBPD, relatively little guidance exists to help STAs with implementation. Hillis<sup>23</sup> and FHWA<sup>24</sup> issued documents focused on strategies to introduce and evaluate the performance of practical design and PBPD initiatives.

Based on feedback from STA personnel and industry stakeholders, Hillis (2016) defined the challenges that influence whether an agency can successfully adopt practical design, anchoring his discussion in six factors — leadership, communication, education, policy, legal issues, and agency culture. Beginning with leadership, three issues help determine whether an agency can successfully introduce practical design. First, executive management should be onboard with practical design and aggressively and vociferously support its use. Second, it is important for an agency to have relatively high risk tolerance and encourage creativity among staff. Lastly, there must be some degree of continuity at the executive level. Executive-level administrators are often political appointees, leading to frequent turnover — establishing an organizational culture committed to practical design can mitigate the effects of turnover; however, it is imperative to receive buy-in from high-ranking staff in all administrations. With respect to communication, an agency should remain in continuous dialogue with key stakeholders (e.g., federal agencies, executive leadership, vendors, contractors, consultants, the public) to share what changes are being introduced as part of a practical design program. Communicating with internal staff is critical as well, because often they are attuned and accustomed to deeply entrenched institutional practices. STAs will also be well-served by coordinating with their local FHWA offices, as building a strong relationship facilitates the implementation of practical design. Education is another challenge that agencies confront. Students and early-career engineers are often taught to prepare designs that conform with standards. Many universities no longer teach design, which shifts the burden to transportation agencies. Because it requires sound engineering judgment to design projects that vary from standards, STAs should prioritize having engineers craft practical designs from their first day of employment.

On the policy front, many STA leaders have incorrectly assumed FHWA, AASHTO, and other federal agencies would not be receptive to practical design. While it is true that some FHWA staffers expressed skepticism or hostility toward design practices that were not standards-based, overall the agency has been very receptive to practical design efforts. Likewise, too often STAs have viewed AASHTO's guidance as binding. This, however, is not the case. AASHTO's guidance documents afford engineers considerable flexibility and are not incompatible with practical design concepts. Some of the AASHTO guidance will benefit from clearer discussions on how guidance should be interpreted and used. Another factor to consider under policy is design exceptions, which historically have been viewed negatively. However, attitudes about design exceptions have thawed, and many agencies now view them as essential for stretching their limited funding. Certainly, in some circumstances legal issues, and more specifically concerns over liability, have slowed down STAs' embrace of practical design. While practical design entails departing from written standards, as Hillis observed, if sound engineering judgment is used to justify a decision, potential legal consequences should be minimized so long as agencies preserve documentation that records the rationale behind design decisions. Another point to consider is whether AASHTO guidance is a legal standard. While Hillis did not make this argument, if AASHTO guidance is treated *qua* guidance — and not as binding standards — it is difficult to foresee a situation in which plaintiffs could persuasively argue that a departure from AASHTO guidelines in constructing or rehabilitating a road or bridge is cause for legal action if engineering staff justify their decisions, account for local context, and record why decisions were made. Vetting decisions with analysis supported by the *Highway Safety Manual* could also potentially offer agencies some degree of legal protection.

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<sup>23</sup> Hillis, 2016.

<sup>24</sup> Federal Highway Administration, 2017.

The final issue to consider when attempting to develop a practical design program is the culture of an organization. As noted, once agency personnel become set in their ways of performing specific tasks it takes considerable effort to make significant changes. Many engineers still view practical design as being associated with heightened risk, which can increase their resistance to it. Therefore, a concerted effort to shift the culture and perceptions at STAs is critical to the success of practical design initiatives. Hillis provided several best practices for overcoming challenges at agencies to facilitate acceptance of practical design<sup>25</sup>. These are reproduced below:

- Announce a Practical Design effort that articulates clear definitions, overarching goals, and ground rules by which the program will be guided. This should come from the executive level.
- Develop an awareness or understanding of the level of design flexibility employed by the agency.
- Develop a spirit of cooperation among DOT leadership and staff, FHWA division staff, political leaders, private industry, and transportation users.
- Use technological advances in communication, such as real-time video conferencing to enhance collaboration among peers, while developing and implementing innovative solutions.
- Provide an implementation oversight function by tasking an individual or committee to ensure projects adhere to Practical Design principles.
- Conduct face-to-face meetings among executive level staff, internal staff, and private industry partners to explain the program and demonstrate leadership's enthusiasm and tenacity for implementation.
- Measure and track progress toward implementation at the organizational and project levels. A reward structure can also be helpful at this stage, as can formal competitions among internal staff and even consultants.

FHWA's *Start-Up Guide: Performance Based Practical Design* offers recommendations for transportation agencies wanting to build a PBPD program. The process FHWA lays out (Figure 3) contains four steps — learning, marketing, rollout, and execution — and subtasks associated with each activity. The first step in establishing a PBPD program is having agency personnel act as champions who advocate for PBPD at the executive and staff levels. This occurs alongside developing knowledge about PBPD and discussions with STAs that have previously launched similar initiatives. Eliciting support from leadership and identifying stakeholders throughout an organization willing to act as partners are critical as well. Agencies should also reach out to external stakeholders at this stage, including vendors, consultants, contractors, local FHWA offices, and other parties who may be affected by a change in agency practices.

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<sup>25</sup> Hillis, p. 11.

**Table 1: Keys to Initiating a Performance-Based Practical Design Program**

Step	Key Element	Details
<b>1. LEARN</b>	<b>Become PBPD Champions</b>	A PBPD Champion at the State agency is someone who truly believes in the PBPD approach. Champions who vocally support PBPD goals at both leadership and staff levels can affect and accelerate cultural change and can often be the key to a successful PBPD program.
	<b>Learn More about PBPD</b>	Talk to your peers in other states about the successes achieved through the implementation of PBPD. Visit FHWA's <a href="#">website</a> to learn more about PBPD. Review the <a href="#">Brief: Overview of Performance-Based Practical Design (PBPD), Frequently Asked Questions, and Case Studies</a> on the website.
<b>2. MARKET</b>	<b>Obtain Executive Buy-In</b>	Educate the leadership of the organization so that they understand and value the importance of PBPD. Support from leadership will facilitate a cultural shift in the entire organization by empowering various departments to work together towards a common goal.
	<b>Gather Stakeholders</b>	Assembling stakeholders from throughout the organization at the outset will foster an atmosphere of partnership. This includes policy, procurement, planning, environmental, design, and construction departments as well as operations and safety groups within the organization. It is also important to form a partnership with the FHWA Division Office and other regulatory agencies, the industry, and consultants.
<b>3. ROLLOUT</b>	<b>Determine the Baseline</b>	Identify the existing processes, tools, resources, and business practices that currently guide agency planning and project development activities.
	<b>Set a Goal</b>	Building on the current state of practice, the stakeholders should establish a goal for their PBPD program and identify intermediate milestones. The goal could compare value of projects to funding, progress towards transportation performance measures, or other measures that are key to the organization.
	<b>Establish a Schedule</b>	Work with your team to develop a realistic timeframe. Implementing a new program and shifting an organization's mindset takes time. Expect the process to take 18 to 24 months from scoping and planning through to deploying PBPD.
<b>4. EXECUTE</b>	<b>Become Familiar with Data and Analytical Tools</b>	Developing alternatives that meet a project's purpose and need with an understanding of safety and operational implications of each alternative is crucial to PBPD. This requires properly trained staff with knowledge of safety and operational tools, such as Safety Analyst, the Highway Safety Manual, the Highway Capacity Manual, and traffic simulation.
	<b>Provide Technical Support to Staff</b>	Change is hard for all professionals and PBPD is no different. Create opportunities to provide training and support for staff in understanding how to use performance tools and resulting data to make more informed decisions. Help staff understand how to view their role and communicate with others in a performance-value mindset. FHWA provides <a href="#">training</a> to agencies interested in learning about how to apply PBPD.
	<b>Create a Sense of Team</b>	Working together as a team can help any organization achieve its goals. This involves effective communication in setting targets or goals as well as recognition for reaching milestones in achieving progress toward a PBPD implementation.

**Figure 3** FHWA Guidance on Developing a PBPD Program

Rolling out PBPD begins with a baseline assessment of the processes, tools, resources, and business practices that have previously guided planning and project development practices. Establishing a baseline is critical for proposing initial goals and milestones for a PBPD program. Once goals have been identified, an agency can settle on a provisional timeline for implementing PBPD — FHWA suggests the process will take anywhere from 18 to 24 months. During the execution phase, agency personnel are responsible for becoming familiar with the analytical tools required to properly evaluate alternative designs (e.g., *Highway Safety Manual*, traffic simulations). Most of the agencies reviewed earlier in this document emphasize the use of the *Highway Safety Manual* to justify design selection. Offering training and support to the staff who are responsible for implementing PBPD is critical, as is building cohesive and collaborative teams.

Agencies should establish clear ground rules related to safety, communication, and quality. All changes should be rigorously and meticulously documented. As part of PBPD rollout, FHWA recommends that agencies reassess the tools, processes, objectives, and design guidance currently in use to distinguish essential practices from those whose use is attributable to institutional inertia and staff preferences. During this reevaluation, agencies can also benefit from developing, revisiting, or revising (depending on its current state) methodologies to select and use design exceptions as well as documentation requirements. Focusing on projects that pair the highest returns on investment with the most significant cost reductions is where STAs should focus their energies. More than anything, the introduction of PBPD provides an opportunity for agencies to empower their staff to rely on their professional judgment and adopt a more flexible approach toward project design.

### **Key Takeaways**

- Practitioners have not settled on a single definition of PBPD or practical design; however, both practices are characterized by a performance-oriented, design-up approach to project development that satisfies the purpose and need (no more) while remaining sensitive to the surrounding context. Savings accrued by designing to the purpose and need, rather than codified design standards, are passed along to tackle projects elsewhere within a corridor or transportation system. Adopting this approach lets STAs pursue systemwide improvements to optimize its performance.
- Agencies have used several metrics to plan for and then assess the performance of projects. Common metrics include vehicle injury and fatal crash rates; pedestrian and bicycle injury and fatal crash rates; benefit-cost ratio; roadway capacity; peak hour traffic flows; congestion; freight movement; funding required for operations, maintenance, and rehabilitation; condition of bridge decks; and environmental quality.
- Common design strategies for reducing overall project costs include obtaining design exceptions for lane and shoulder widths (typically to construct them narrower than guidance or standards specify); reducing the number of lanes built as part of major projects (if safety and operations will be unaffected); use of alternative shoulder designs; installation of low-cost safety countermeasures, such as signs, rumble stripes, and striping; selecting alternative designs or alignments to lessen right-of-way or environmental mitigation costs; and the introduction of active traffic management.
- Developing a robust PBPD or practical design program at an STA requires buy in from staff across the organization, establishing a baseline understanding of current practices and policies, articulating clear goals and performance metrics to assess the effectiveness of the program, offering support and training to personnel, and once the program is in place working to apply its principles consistently.



## Chapter 2 State Transportation Agency Performance Measures

This chapter summarizes practices used by state transportation agencies (STAs) to identify performance measures, and advances recommendations for KYTC to consider as it establishes measures to guide the safe, efficient, and long-term cost-effective investment in Kentucky’s roadways. A review of all 50 states to determine what performance measures their transportation agencies use found that state practices are mixed. Some states have developed independent performance dashboards to monitor performance measures. Others list performance measures only in their state transportation plans or have not established any. Moreover, the range of measures established by states varies widely. Common performance metrics include pavement conditions, traffic fatalities, hours of delay, operational efficiency, air quality, projects delivered on-budget, workforce development, and number of DMV transactions processed. Figure 4 illustrates the performance dashboard used by the Idaho Transportation Department (ITD).

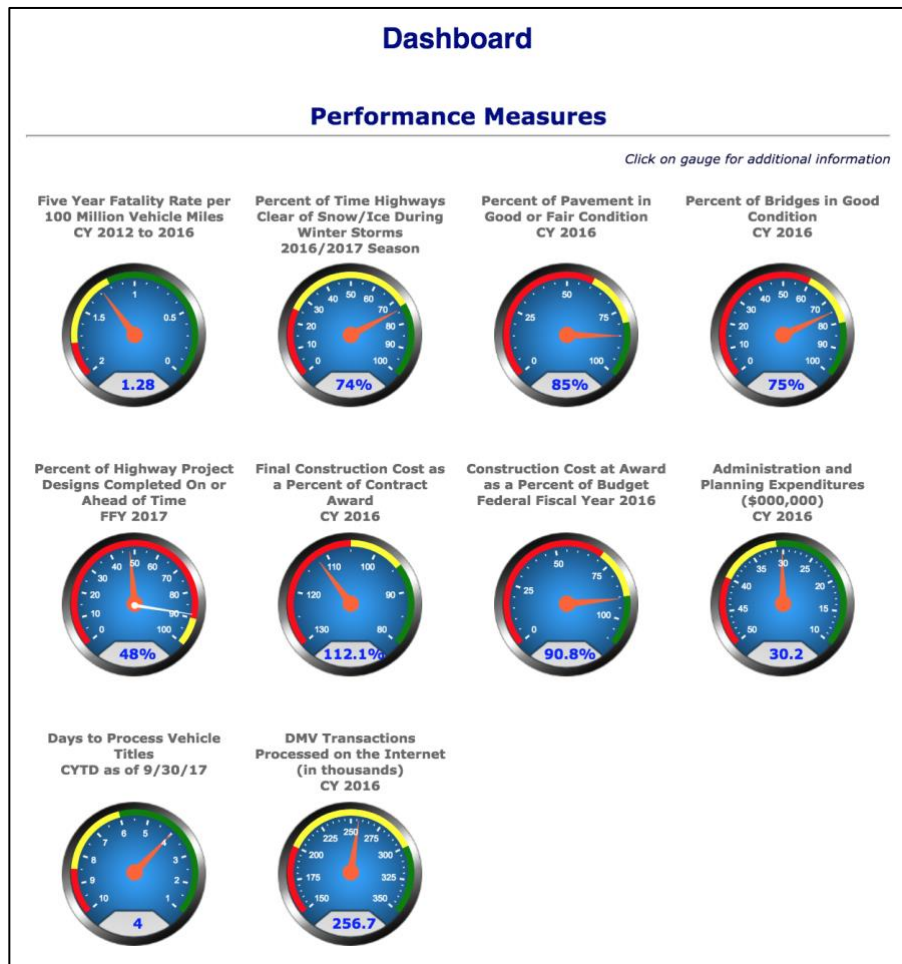
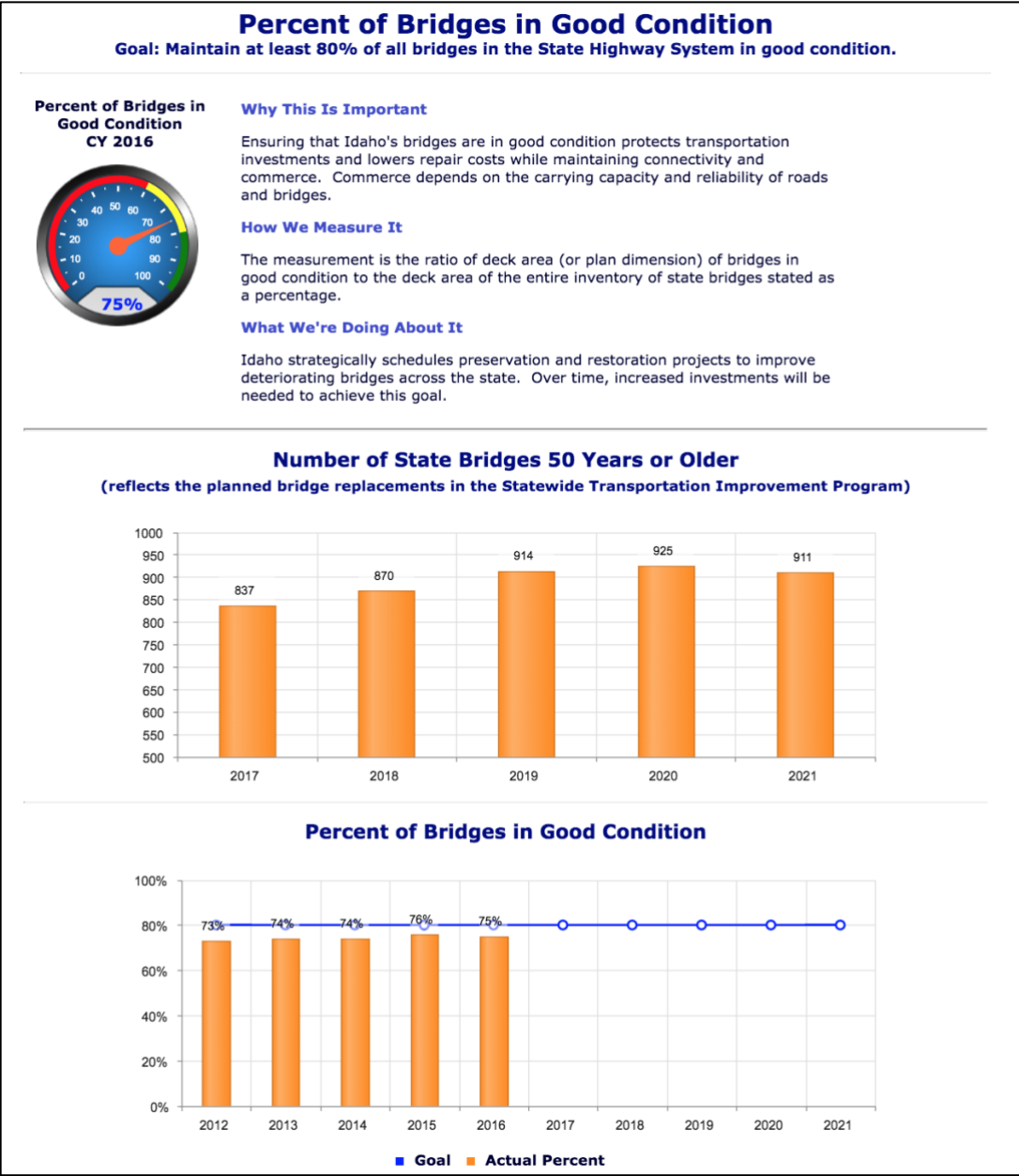


Figure 4 ITD Performance Dashboard

Along with performance measures, some states have set performance goals for each measure while others have not. Figure 5 shows ITD’s performance goals for Percent of Bridges in Good Condition and the level of current performance. The agency aims to maintain 80 percent of its bridges in good condition.



**Figure 5** ITD Bridge Condition Goals and Historical Performance

**Safety Performance**

Almost every state has a stated goal of having zero roadway fatalities. Several states hold this as a long-term goal and have intermediate-range targets for fatality rates. Notably, the Oregon Department of Transportation (DOT) states “Oregon’s goal is zero fatalities, but realistic targets are set based on the desire to reduce fatality rates gradually over time to achieve the longer-term goal of zero. Oregon’s 2015 rate was 1.24 fatalities per vehicle miles traveled, which is above the target at 0.86 per 100 million VMT.” While Oregon has set a definitive target to monitor fatality rates, other agencies, such as the Missouri DOT (MoDOT), have specified desired trends but lack a set target. They are monitoring performance to ensure it follows those trends.

Agencies have identified strategies for achieving performance measure goals. Oregon’s DOT has identified specific factors contributing to fatal crashes, such as not wearing seatbelts or alcohol use, while MoDOT has pinpointed parties within the agency responsible for tracking and attaining desired performance.

The Iowa DOT has adopted a novel approach by monitoring safety-related projects on the state road network. A key performance measure the agency monitors is “Miles of New Paved Shoulders Awarded for Construction.” The goal of the program is to construct paved shoulders on the National Highway System and other portions of the Primary Highway System with annual average daily traffic counts greater than or equal to 3,000. The sole purpose of this measure is to bolster the safety of Iowa roadways, as cash data indicate that on average 40 percent of the state’s roadway fatalities involve single-vehicle, run-off-the-road crashes.

#### *Recommendation for KYTC*

Taking a cue from the Iowa DOT approach, KYTC should consider a similar effort that identifies design and construction activities as a primary performance measure shown to have an impact on safety, such as improved shoulders. The Strategic Highway Safety Plan will serve as a good starting point to develop this measure because it identifies what areas the state is focusing on to improve safety. Two areas that should be emphasized within highway design and operation are intersection and roadway departure crashes. For each focus area, 13-16 potential solutions are identified for implementation, including improved access management, improved sight distance, implementation of innovative intersection designs, installation of centerline and shoulder rumble strips, improved superelevation of curves, and removal of objects in clear zone.

An alternative performance measure is tracking the number of high crash locations or high crash corridors addressed through *any* roadway improvement program (e.g., maintenance activity, capital improvement project, or Highway Safety Improvement Program [HSIP]). Monitoring the number of high crash sites addressed each year will help project development and project delivery staff keep a focus on these areas.

#### **Operational Performance**

Most STAs name the efficient movement of people and goods as a primary goal. However, performance measures related to operational performance are relatively uncommon. The establishment of performance goals is typically restricted to major routes or interstates exclusively. For instance, MoDOT monitors travel time reliability within the states four primary urban areas during AM and PM rush hours. But the challenge of using a measure such as this is the limited data available to actively monitor performance. Without sufficient data, there can be only limited quantification of delay impacts, typically focused on urban areas where traffic is actively managed. A downside to this approach is that unmonitored areas may be overlooked for congestion or delay issues that could otherwise be resolved easily. The recent roundabout project in KYTC District 10 serves as an example. The project reconstructed an intersection that previously operated as a four-way stop due to safety concerns. During the AM and PM peak periods, delays exceeding 10 minutes were common. However, delays remained undocumented until reconstruction of the intersection was begun.

#### *Recommendation for KYTC*

KYTC has purchased historic traffic data from NAVTEQ that provides average hourly travel speeds for every roadway link in Kentucky. This dataset can be used to identify performance trends and operational changes during peak periods compared to off-peak or free-flow periods. We recommend that KYTC use this dataset to develop performance indices that will identify high levels of congestion on state routes. The Cabinet should set performance measures aimed at reducing the number of congestion hot spots. Urban areas (e.g., Louisville, Lexington) may require special attention because dense urban development results in unique traffic patterns compared to suburban or rural locations. Capacity solutions tend to be more expensive to implement in these settings. One potential performance measure is the number of corridors or

intersections having a peak travel time at least twice that of off-peak times. Tracking this metric will help KYTC address congested areas with operational or capital improvements. We suggest performing a detailed analysis of the NAVTEQ dataset before identifying specific performance goals and to specify a manageable number of sites prior to adoption. One need in this area is documentation of where congestion occurs on Kentucky roadways and its impact on statewide mobility. A comprehensive assessment of conditions related to mobility does not exist as it does for other critical measures of transportation system performance, such as safety and roadway/bridge conditions.

### Asset Management and Condition Monitoring

Most states currently monitor pavement and bridge condition; a majority set the goal of having 80 percent of bridges and pavements in good condition. Other states, however, establish inverse goals that define unacceptable performance and where focus should initially be set. For example, the Massachusetts DOT (MassDOT) tracks the percentage of roadways rated in poor condition. Its goal is for less than 10 percent of the roadway being rated as such. Agencies use the Bridge Health Index or FHWA Sufficiency Rating to monitor and evaluate bridge condition. For roadway monitoring, agencies typically rely on the pavement serviceability index (PSI), which uses the International Roughness Index (IRI), or a roughness index supplemented with data on joint distress and faulting/rutting (e.g., Kansas DOT, MassDOT).

MoDOT and MassDOT created bridge repair programs to address deficiencies identified by performance monitoring. For example, the Missouri Safe and Sound Bridge Improvement Program addressed 802 out of 1093 bridges identified as being in serious or poor condition. MoDOT rehabilitated 248 bridges while the remaining 554 were replaced through a single design-build contract. The ambitious program let the agency take corrective action on 80 percent of its deficient bridges within a four-year period.

### Recommendation for KYTC

KYTC should consider a performance measure like those adopted by MoDOT and MassDOT with the aim of identifying assets in unacceptable condition. Doing so will facilitate the Cabinet’s efforts to single out assets most urgently needing repair from those which are potentially sufficient from an operational and structural perspective despite not being in good condition. Using a triage approach, the most endangered assets will receive treatment first, with desired upgrades or improvements made once critical repairs have been completed.

### Project Delivery

A final performance measure used consistently across states is project delivery monitoring. Project lettings are usually tracked quarterly to ensure projects are delivered on-time and on-budget (e.g., Indiana DOT; Figure 6). To monitor costs, other states have chosen alternative measures. MoDOT uses a metric called “Percent of Programmed Cost compared to the Final Project Cost,” the goal of which is to improve the accuracy of project programming. The agency has a target of 0 percent difference between programmed and final costs.

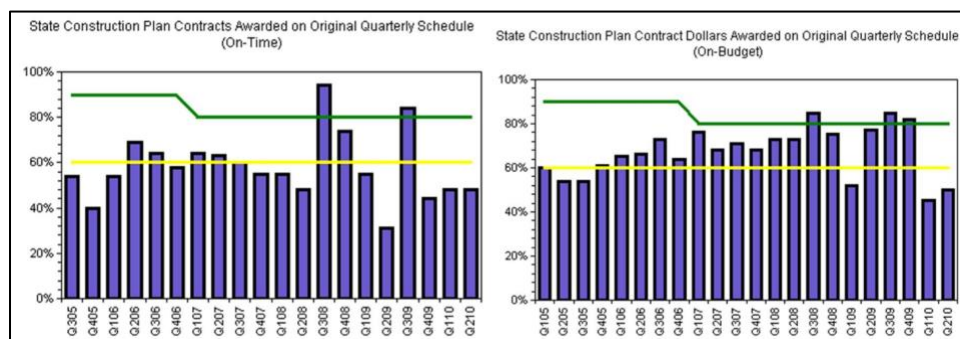


Figure 6 Indiana DOT Project Delivery Performance Measures



### *Recommendation for KYTC*

KYTC should consider adopting a performance measure focused on projects delivered to letting on time and on budget as scheduled based on contract letting schedules. This will ensure projects are delivered to meet the Cabinet's budgetary plans.

### **Conclusions**

Identifying and implementing performance measures is critical for KYTC's efforts to fulfill its mission and comply with MAP-21 (and FAST Act) requirements. STAs use a variety of performance measures to direct their activities. The most useful performance measures are 1) quantifiable, letting agency personnel determine if their activities are helping the organization achieve its goals, and 2) applicable to the duties and responsibilities of a particular agency. For example, when examining performance measures related to safety, fatality rates are easily quantifiable; however, fatality rates depend on many factors, such as seat belt usage, alcohol usage, vehicle mileage, and roadway design. Some of these are beyond an STA's control. However, using a performance measure such as the Iowa DOT's one for shoulder improvement, results in setting targets an agency can achieve entirely through its own volition. Furthermore, as demonstrated by MassDOT and MoDOT's asset management rating systems, performance measures can be used to focus activities on the most urgent priorities. Establishing a goal of having less than 10 percent or less of bridges rated as poor offers clearer direction on where to make investments, compared to setting a goal of keeping 80 percent of bridges in good condition. KYTC currently holds the data necessary to develop and monitor systemwide performance for all the areas discussed above. In doing so, it will be able to sharpen the focus and direction of Department of Highway activities and improve the overall condition of the highway system in a cost-effective manner.