SCAN TEAM REPORT

NCHRP Project 20-68A, Scan 21-03

Successful Approaches to Setting Project Development Budgets

Supported by the

National Cooperative Highway Research Program

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The purpose of each scan, and of Project 20-68 as a whole, is to accelerate beneficial innovation by facilitating information sharing and technology exchange among the states and other transportation agencies and identifying actionable items of common interest. Experience has shown that personal contact with new ideas and their application is a particularly valuable means for such sharing and exchange. A scan entails peer-to-peer discussions between practitioners who have implemented new practices and others who are able to disseminate knowledge of these new practices and their possible benefits to a broad audience of other users. Each scan addresses a single technical topic selected by AASHTO and the NCHRP 20-68 Project Panel. Further information on the NCHRP 20-68 U.S. Domestic Scan program is available at https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=1570.

This report was prepared by the scan team for Domestic Scan 21-03, *Successful Approaches to Setting Project Development Budgets*, whose members are listed below. Scan planning and logistics are managed by Arora and Associates, P.C.; Harry Capers is the Principal Investigator. NCHRP Project 20-68 is guided by a technical project panel and managed by Sid Mohan, NCHRP Program Officer.

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Disclaimer

The information in this document was taken directly from the submission of the authors. The opinions and conclusions expressed or implied are those of the scan team and are not necessarily those of the Transportation Research Board or its sponsoring agencies. This report has not been reviewed by and is not a report of the Transportation Research Board or the National Academies of Sciences, Engineering, and Medicine.

Scan 21-03
Successful Approaches to Setting Project Development Budgets

REQUESTED BY THE

American Association of State Highway and Transportation Officials

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Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
Caltrans	California Department of Transportation
CE	Construction Engineering
CFL	Central Federal Lands Highway Division (FHWA)
CRA	Cost Risk Assessment
DOT	Department of Transportation
ePM	Electronic Program Management (UDOT)
EV	Earned Value
FHWA	Federal Highway Administration
GDOT	Georgia Department of Transportation
MaineDOT	Maine Department of Transportation
MDOT	Michigan Department of Transportation
MnDOT	Minnesota DOT
NCHRP	National Cooperative Highway Research Program
NDOT	Nevada Department of Transportation
ODOT	Oregon Department of Transportation
PE	Preliminary Engineering
PennDOT	Pennsylvania Department of Transportation
PS&E	Plans, Specifications, and Estimates
RW	Right-of-Way
STIP	Statewide Transportation Improvement Program
TxDOT	Texas Department of Transportation
UDOT	Utah Department of Transportation
VDOT	Virginia Department of Transportation
WSDOT	Washington State Department of Transportation

Executive Summary

Transportation projects require significant investments of funds and resources. The cost of these projects includes not only the cost of construction but also the cost of project development, including scope development, environmental review and mitigation, preliminary engineering, right-of-way, utilities, final design, public engagement, and construction engineering. These costs of project development are a significant percentage of the total cost of transportation projects.

While agencies have devoted much time, effort, and expense to estimate the cost of construction, it is believed that the estimation, budgeting, and tracking of project development costs can benefit from improved processes. The purpose of this domestic scan is to identify successful approaches to setting project development budgets.

The scan team heard online presentations from 13 transportation agencies regarding their methods, tools, and processes for estimating, budgeting, and tracking the cost of project development for transportation projects.

Summary of Findings

Findings and observations were noted following each presentation as roses (successful processes), buds (new ideas with promise), or thorns (challenges to be addressed). One week after the presentations had been completed and the roses, buds, and thorns were recorded, the scan team met to finalize its list of findings. These findings and examples from the agency presentations were placed in categories (general observations, scope development, cost estimating, risk, dashboards, tools and data systems, contractor involvement, communication, and miscellaneous) in order to compare the variety of methods, procedures, and tools used by these agencies.

Recommendations

The following are the scan team's recommendations based on findings determined from presentations and materials provided during the scan and finalized during a scan team meeting.

Scoping/Cost Estimating

- The use of standard templates, data systems, and tools for project scoping and cost estimating is a best practice that should be employed.
- It is recommended that manuals developed to guide the scoping process require a review of statewide plans and standards to ensure the consistency of project scopes with those documents.
- The use of an early PE phase as part of the development process prior to programming the construction phase is recommended for more complex projects to identify issues early on, such as environmental risks and potential right-of-way acquisition.

- The use of an owner's scope contract performed by a consultant to perform scoping and cost estimating can be beneficial in providing a different perspective and supplementing in-house resources.
- The use of former construction estimators or consultants with expert knowledge from a contractor's perspective to verify estimates, schedules, and review constructability can help to provide a valuable second opinion.
- Sharing planning level tools for scoping and estimating with local agencies can improve Department of Transportation project proposals.
- Agency cost estimating manuals and materials should be developed and updated regularly.
- The use of a flat percentage of construction costs for estimating the cost of project development and CE phases based on historic averages is an appropriate tool to use for typical non-complex projects with significant construction cost histories.
- A uniform policy on escalation (e.g., inflating costs to the midpoint of a phase) is recommended to provide consistent guidance across all projects. (Training and guidance should be considered to assist project managers.)
- Cost estimating programs and systems should capture history and assumptions for future reference. The basis of the estimate should be updated at milestones, regular reviews, or annually, whichever comes first.
- Focus more attention on those 20% of bid items that result in up to 80% of costs or higher risk during scoping and project development.

Risk-Based Analysis

- Estimates and budgets should include risk-based contingencies to account for unknown and identified risks.
- Scheduled risk analysis should be considered for high-profile and complex projects.
- Development of a robust risk assessment approach that is scalable to total project cost and/or complexity is recommended.
- A project closeout process that documents lessons learned, actual resources used, and the effectiveness of the ways that anticipated risks were eliminated or mitigated is recommended.
- Consider using a separate risk contract to evaluate risk and quantify outside factors that might impact the project's cost or schedule.

Budgeting/Tracking

- While the cost of construction is a major portion of project costs, the cost of project development is significant and should also be considered and budgeted.
- Dashboards and tools to budget and track project development costs in addition to construction costs will communicate progress to decision-makers and the public and assist agencies to identify actual resource needs to deliver the program.

- Project costs should be compared to planning estimates to identify problems early so that necessary action can be taken proactively.
- A change management process should be employed to aid in proactively managing project budgets and schedules that enable programming staff to better manage overall program budgets. An efficient change management process will keep the project management focus on delivering the project and provide accountability and transparency.
- Implementation of Earned-Value (EV) analysis that provides regular reports and ties schedules and resources can be beneficial in identifying potential problems early on.
- For work done by agency staff, it is important to establish a mindset of an owner-operator to effectively budget and track in-house project costs. A balance should be struck between an owner-operator mindset, where staff tend to spend as much time as needed to deliver near-perfect products, and the need to work within established budgets.

Tools and Data Systems

- Programs and systems that "talk" to each other are beneficial in sharing information and saving historic data for future reference.
- It is important to consider technology costs, security of data, maintenance, and the quality of data.
- Updating and replacing legacy project development systems is important but costly and time consuming and should be done with significant planning and deliberation.

Communication

- Peer exchanges with transportation agencies and contractors to discuss project development and construction are both beneficial and encouraged.
- Consider a strategy for communicating the accuracy of project costs when releasing information on risk-based contingencies and cost estimates to avoid implying unwarranted accuracy.
- Agencies should define the terms used in project development and be consistent in communicating them.

Finally, an implementation strategy is presented to share findings and recommendations of the scan with others in the transportation community.

Introduction

Transportation agencies are responsible for planning, programming, designing, and delivering multimodal transportation projects. These projects are important capital improvements that provide benefits to the traveling public and the economy. They require significant investment of funds and resources, so it is important that responsible agencies focus their efforts to plan, budget, and administer the delivery of these projects accurately and efficiently.

The cost of these projects includes not only the cost of construction, but also the cost of internal staff and external consultant services for project development activities such as scope development, environmental review and mitigation, preliminary engineering (PE), final design, public and community engagement, and construction engineering (CE). While agencies have devoted much time, effort, and expense to estimate the cost of construction, it is believed that the estimation and tracking of project development activities has not always received adequate attention. It is the objective of this scan [1] to identify the best practices of leading transportation agencies to estimate, budget, and track the costs of project development and recommend how agencies can improve their processes.

Some agencies have been recognized as having successful approaches to estimate and track costs for project development. Several of those agencies were invited to participate in this scan to share their methods and procedures with the scan team.

The scan team heard presentations from 12 state transportation agencies and one federal agency responsible for projects on federal lands. In addition to the seven state Departments of Transportation (DOTs) and the Central Federal Lands (CFL) Highway Division of the Federal Highway Administration (FHWA) that participated as scan team members, five additional state DOTs participated. Those state DOTs were the California Department of Transportation (Caltrans), the Nevada Department of Transportation (NDOT), the Oregon Department of Transportation (ODOT), the Pennsylvania Department of Transportation (PennDOT), and the Virginia Department of Transportation (VDOT). The presentations described many of the guidance manuals, tools, and methodologies used to scope, estimate, budget, and track expenditures and performance for the delivery of projects. Several new and innovative tools and methods were discussed, as were several barriers and challenges.

The scan was conducted virtually by webinar, with 13 individual presentations during a one-week period. The following week the scan team met by webinar to discuss the findings and recommendations that emerged from the presentations. This report documents those findings and recommendations.

1 U.S. Domestic Scan Program "21-03 Prospectus." 21-03 – Successful Approaches to Setting Project Development Budgets

Scan Findings and Observations

This section describes the guidance, tools, and methodologies that the scan team identified as good practices, new ideas with potential, or challenges that emerged from the presentations.

General Observations

Some general observations were made related to methodologies used by the presenting agencies. Nearly half of the agencies that presented information to the scan team established budgets for the total project cost of transportation projects, including preconstruction costs. The remaining agencies developed estimates for construction and preconstruction costs but only budgeted for the cost of construction and contingencies.

Of those agencies that developed budgets for the total project cost, a few established these budgets early on and use them to evaluate the performance of estimators throughout the remainder of the project. It was stated that it is difficult to estimate accurately and that it requires more care during the preliminary scoping and estimating process. Several other agencies establish the budget for the total project cost but adjust it annually or at milestones as more information is available.

Caltrans budgets for the total project cost and sets its budget early in the project development process; managers are held to this budget throughout the project development process. Caltrans pointed out that it is not intuitive for staff to spend what they may consider extra time tracking support costs as Caltrans owns the system. It was explained this is like a homeowner who doesn't consider the time they spend working on their home. Instead, a change in perspective was needed so that staff would consider their position more like a consultant working for the California Transportation Commission. As such, it is helpful to establish a culture that understands striking a balance between an owner-operator mindset, where staff tend to spend as much time as needed to deliver near-perfect products, with the need to work within established budgets.

In Maine, the DOT (MaineDOT) budgets for the total project cost, including all phases of project development. Budgets are set using input from several committees representing various functions and areas of responsibility. Funding is allocated each year into categories, including supplemental needs, deferred efforts, PE only and ready for construction, and unfunded candidates.

Minnesota DOT (MnDOT) budgets for the cost of construction and does not currently budget for project development costs. However, MnDOT notes that the estimated cost for project development activities had grown from approximately 20% of the program to approximately 29% as a result of more public and stakeholder engagement and additional work. For that reason, MnDOT plans to begin budgeting for the total project costs in the future.

ODOT currently budgets for the total project cost at the time of scope approval. However, it is now considering placing these funds into an undesignated "bucket" for Statewide Transportation Improvement Plan (STIP) funding until more information is known regarding the project and market conditions.

The Utah Department of Transportation (UDOT) also budgets for total project costs. Estimates are reviewed at important milestones (30%, 60%, 90%, and PS&E) to verify that the total budget is below the total amount approved by the Utah Transportation Commission. Additionally, due to a recent increase in state funding from sales tax, the department has begun budgeting based on projected cash flow. This has resulted in a challenge to estimate short-term project expenditures to match short-term cash flow receipts.

VDOT budgets for the total project cost at the milestone for final scoping. Since project managers' performance is based on this budget, it was stated that some project managers delay signing off on final scoping to have more information on quantities that improved the project estimate.

Scope Development

The development of a project scope is an important early phase of project development. A few agencies pointed out the importance of spending more time and effort up front during scoping. It was stated that this extra effort will often be beneficial in the long run.

Washington State DOT (WSDOT) and ODOT both stated that it is beneficial to assign more-experienced staff to perform scoping. They indicated that using less-experienced staff during scoping can lead to problems later, as serious issues can be overlooked.

It was also stated that it is beneficial to assemble cross-functional teams for initial scope development to bring a variety of perspectives that a more narrowly focused team would not provide. For this reason, MaineDOT uses different functional committees working together to scope projects and set project budgets.

MnDOT mentioned that the use of budgets will provide incentive to establish accurate scopes so that budgets are less likely to be modified. This emphasis on scoping creates a challenge as agencies struggle to assign experienced personnel to the scoping process. These staff are often the same ones needed to get projects to the letting on time. A couple of the agencies indicated that dedicated scoping groups were formed to address this issue.

Several agencies begin their scoping process by soliciting needs from district staff. Georgia DOT (GDOT) begins its scoping process with a concept development report using information from district staff. To provide resources to supplement GDOT staff, owner's scopes are prepared using consultants to develop purpose, need, and scope for proposed projects. This information is used to develop a request for qualifications to design the project. Because this provides additional scrutiny for the scope of work, it typically reduces the amount of scope creep that might otherwise occur.

Agencies use a variety of methods for scope development. These methods are often based on the type, size, and complexity of projects. NDOT uses a Microsoft Excel-based tool called Wizard to develop planning-level scopes and estimates for projects. Wizard is a user-friendly program that uses dropdown menus to guide users. It includes escalation amounts to account for inflation based on the year of construction and uses percentage amounts of construction cost estimates to estimate the amounts for PE, right-of-way (RW), environmental review, and CE.

Following initial planning-level scope development using Wizard, if a project still looks promising, NDOT uses a more robust or enhanced scoping process. This process is completed by a team that produces a preservation report for each project. Cost estimates are prepared using estimates of paving quantities and additions for other items. Additions to scope suggested by district staff and other specialists are approved or rejected by the NDOT design chief. The completed preservation report

is then used to program and schedule the project. The final preservation report, or "scoping report," provides estimated cost breakdowns by division and work type for tracking.

ODOT scopes pavement projects using a desk scope that generates a list of projects. These projects are then field scoped and estimated. Following approval by ODOT staff and management, projects are sent to the Oregon Transportation Commission for adoption.

Michigan DOT (MDOT) Projects and Contracts engineers use the Michigan Department of Transportation Project Scoping Manual[2] while working with region offices to develop scopes for projects. The scoping solution is based on road and bridge condition data using a series of templates.

MDOT indicated that an early PE phase, prior to programming the construction phase, is often beneficial for complex projects. It was stated that such an early PE phase can identify issues early on and provide a high-level cost estimate. This also allows an opportunity for adjustments before committing additional resources to the project.

VDOT has a six-year plan of projects that are selected using the agency's SMART SCALE priority allocation program. This program prioritizes projects that are submitted for consideration by VDOT districts, localities, regional planning organizations, and municipalities. These projects undergo an early preliminary concept analysis that is used to determine the need and priority for the work. Following this analysis, scoping of the projects is completed to verify that needs are met and match projects with available funds.

PennDOT uses a scoping/field view update to review and modify a project's scope as determined by a field review. An executive programmatic management committee reviews significant changes to scope that result in greater than a $2.5 million increase in the cost of a phase (typically construction).

Finally, ODOT pointed out the importance of verifying that scopes are consistent with statewide transportation system plans and standards. It was stated that in some cases departments responsible for scoping are not familiar with or don't seek access to planning documents that provide these system plans and standards.

Cost Estimating

Agencies often spend more time and effort estimating construction costs than phases of project development, even though project development costs amount to a significant percentage of the total project costs. Caltrans and MnDOT both pointed out that approximately 30% of the total cost of their projects are for support or project development activities and therefore deserve significant attention.

The overwhelming majority of agencies participating in the scan estimate project development costs based on a percentage of the estimated cost of construction (also referred to as a support to capital construction cost ratio). Caltrans is one of a few agencies that uses a bottom-up method of estimating construction and project development costs. Caltrans indicated that it has a series of spreadsheets that estimate the cost of individual phases of project development using a bottom-up approach. These estimates are then confirmed using top-down tools that identify similar projects to verify estimates.

Several agencies, including Caltrans, have similar cost-estimating components. These components include a base cost that is realistic (i.e., without additional risk added), an allowance for issues that are known but not yet detailed for estimating purposes, escalation for inflation, and adjustments for

2 Michigan Department of Transportation Project Scoping Manual, https://mdotcf.state.mi.us/public/docs/design/files/scopingmanual/Scoping_Manual.pdf

unknown risk. The contingencies that are included in this estimate decrease as the letting approaches and more is known about the project. Support cost contingency is represented as the known risk amount. A figure showing Caltrans' cost estimate components is shown in **Figure 2-1**.

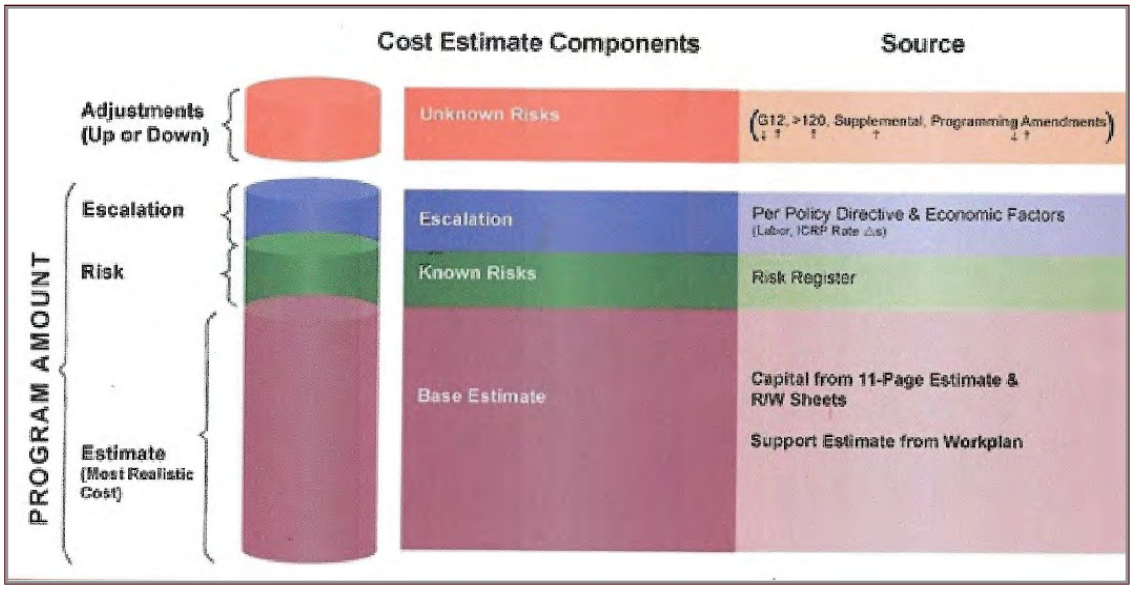


Figure 2-1. Caltrans cost estimate components

CFL establishes the budget for construction of a project early on and includes contingencies for risks and unknowns that are reduced as project development continues. The CFL cost estimating matrix (**Figure 2-2**) illustrates the percentage of contingency to allow during various phases of project development.

Table 1: Cost Estimating Matrix

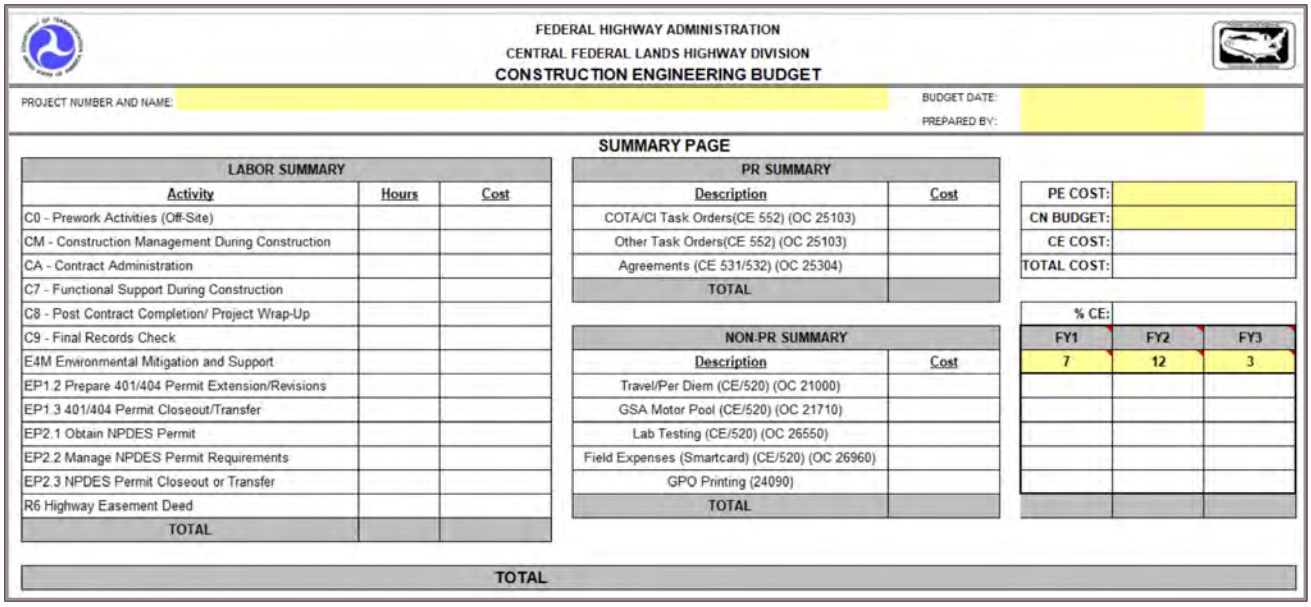
Project Development Level	Class Description	Purpose of Estimate	Methodology	Approximate Contingency Range *
Project Scoping	Class C	• Set the baseline cost • Verify the Program amount	• Historical-bid based • Cost per mile	25% to 35%
Preliminary Design (15% and 30%)	Class B	• Supports decision-making • Control of project scope and schedule	• Historical-bid based • Cost-based	20% to 30%
Intermediate Design (50%)	Class B	• Supports decision-making • Control of project scope and schedule	• Historical-bid based • Cost-based	10% to 20%
Intermediate Design (70%)	Class A	• Supports decision-making • Control of project scope and schedule	• Historical-bid based • Cost-based	10% to 20%
Final Design (95% and 100%)	Class A	• Obligate construction funds • Evaluate contractor's bids	• Historical-bid based • Cost-based	None

* The contingency is a percentage of the estimated project cost.

Figure 2-2. CFL cost estimating matrix

CFL indicated that efforts are made during scoping to identify items of work that contribute the most to construction costs (e.g., asphalt and roadway excavation) and make efforts to develop quantities and unit prices for those items. A percentage of the cost of construction is used for other items. An average cost per mile is also used for validation.

CFL estimates the cost for PE and CE in conjunction with the scope of work and budgets for those amounts. PE budgets are established early on using budget templates based on historic data for similar work. Each discipline provides information for its estimate of work into the budget template for each task. Budgets not only include dollars, but also staff hours and resources. Budgets for CE including anticipated costs for staffing, overtime, and per diem are prepared using a worksheet (**Figure 2-3**). This amount is set as a placeholder and updated as the project gets closer to construction.



FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION
CONSTRUCTION ENGINEERING BUDGET

PROJECT NUMBER AND NAME:
BUDGET DATE:
PREPARED BY:

SUMMARY PAGE

LABOR SUMMARY		
Activity	Hours	Cost
C0 - Prework Activities (Off-Site)		
CM - Construction Management During Construction		
CA - Contract Administration		
C7 - Functional Support During Construction		
C8 - Post Contract Completion/ Project Wrap-Up		
C9 - Final Records Check		
E4M Environmental Mitigation and Support		
EP1.2 Prepare 401/404 Permit Extension/Revisions		
EP1.3 401/404 Permit Closeout/Transfer		
EP2.1 Obtain NPDES Permit		
EP2.2 Manage NPDES Permit Requirements		
EP2.3 NPDES Permit Closeout or Transfer		
R6 Highway Easement Deed		
TOTAL		

PR SUMMARY	
Description	Cost
COTA/CI Task Orders(CE 552) (OC 25103)	
Other Task Orders(CE 552) (OC 25103)	
Agreements (CE 531/532) (OC 25304)	
TOTAL	

NON-PR SUMMARY	
Description	Cost
Travel/Per Diem (CE/520) (OC 21000)	
GSA Motor Pool (CE/520) (OC 21710)	
Lab Testing (CE/520) (OC 26550)	
Field Expenses (Smartcard) (CE/520) (OC 26960)	
GPO Printing (24090)	
TOTAL	

PE COST:	
CN BUDGET:	
CE COST:	
TOTAL COST:	

% CE:		
FY1	FY2	FY3
7	12	3

TOTAL

Figure 2-3. Central Federal Lands Highway Division construction engineering budget worksheet

CFL also ties resources to schedules as part of the budgeting process. This allows managers to view all hours assigned to a project, including the hours assigned to staff, which helps to determine how shifting staff from one project might affect other projects.

Some agencies have published cost estimating manuals. Guidance for cost estimating at GDOT is documented in Georgia Department of Transportation Policy 3A-9 Cost Estimating Purpose[3]. It also defines how newly programmed project budgets are created, monitored, and processed for all phases, including PE, RW, utilities, and construction budgets.

PennDOT's policies and procedures for developing, documenting, and reviewing construction cost estimates throughout the project development process are contained in its Pennsylvania Department of Transportation Publication 352, 2018 Edition, Estimating Manual[4]. The manual contains a series of cost driver templates that guide the user through the analysis. The agency provides training and webinars to staff and municipal partners on procedures for cost estimating.

3 Georgia Department of Transportation Policy 3A-9 Cost Estimating Purpose, http://mydocs.dot.ga.gov/info/gdotpubs/Publications/3A-9.pdf

4 Pennsylvania Department of Transportation Publication 352, 2018 Edition, Estimating Manual, https://www.dot.state.pa.us/public/PubsForms/Publications/PUB 352.pdf

According to WSDOT, its cost estimating manual is consistent with the best practices recommended by National Cooperative Highway Research Program (NCHRP) Report 574, Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction[5].

A number of agencies use AASHTOWare tools. GDOT uses AASHTOWare Project Estimation™[6] as its construction cost-estimating software. It contains information on all the agency's historical pay items and costs. Additionally, contingency is added to the estimate based on the project as provided in Policy 3A-9 above. Inflation is also added by the Office of Financial Management based on the number of years projected before letting. Estimates for RW, utilities, and construction are updated every year and at significant milestones to verify that the project is staying on track and as an early warning if the scope has changed.

MaineDOT uses AASHTOWare Estimator (Infotech Estimator™[7]) to develop construction estimates. Estimates for PE and CE are made based on percentages of the estimated cost of construction. Estimates are updated annually and at established milestones. The estimate will contain an amount for contingency that reduces to zero by the time of PS&E approval. Any significant changes to the project that are needed once it is approved need to be approved by a Work Plan Management Committee that reviews the changes before, they are sent on to an executive committee for final approval.

In the past, MDOT used worksheets with average unit costs to estimate construction costs. Cost estimates were further adjusted if market conditions changed significantly. Additionally, engineering judgement may be applied for issues such as complex maintenance of traffic, night work, and limited access due to Section 4(f) impacts.

MDOT has recently begun using AASHTOWare Project Preconstruction™ software for estimating. However, some project managers are reluctant to use the AASHTOWare product as they are more familiar with Excel spreadsheets. An advantage to using the AASHTOWare software is that it provides more uniformity for the estimating process. Inflation is added to projects on a scale that varies from 4% for the first year to 21.7% for year five (4% compounded annually).

MDOT uses a percentage of the construction cost estimate to estimate the cost of PE and CE. Tables from the existing Michigan Department of Transportation Project Scoping Manual (**Figure 2-4** and **Figure 2-5**) show the percentages to use for PE and CE based on project type and estimated construction cost.

5 (NCHRP) Report 574, Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction, https://www.trb.org/Publications/Blurbs/158464.aspx

6 AASHTOWare Project Estimation™, https://www.aashtowareproject.org/apr-est

7 Infotech Estimator™, https://www.infotechinc.com/estimator/

Table 8-4: Other Factors That May Impact PE Cost

Type of Work	Estimated Cost *	% of Total Cost
Rehabilitation & Reconstruction/Replacement CMAQ/Safety (T&S)	$0 to $500,000	15
Rehabilitation & Reconstruction/Replacement	$500,000 to $3 Million	12
Rehabilitation & Reconstruction/Replacement	$3 Million to $6 Million	8
Rehabilitation & Reconstruction/Replacement	$6 Million and above	5
CPM (Road)	All	3
CPM (Road)	All (Justified)	5
CPM (Bridge)	All	10

- Note: PE percentages are applied to the construction subtotal

Figure 2-4. Michigan DOT preliminary engineering estimate from existing Scoping Manual

Table 8-5: Other Factors That May Impact CE Cost

Type of Work	Estimated Cost *	% of Total Cost
Rehabilitation & Reconstruction/Replacement	$0 to $2 Million	12
Rehabilitation & Reconstruction/Replacement	$2 Million to $10 Million	10
Rehabilitation & Reconstruction/Replacement	$10 Million and above	7

Figure 2-5. Michigan DOT construction engineering estimate from existing Scoping Manual

Agencies indicated that a regular review of the actual percentage cost of project development was helpful to determine if adjustments to planned percentages are needed. Agencies also mentioned that opportunities for improving estimates were found by comparing actual costs to the initial planning estimate.

MDOT has recently completed analysis of the actual costs for PE and CE as a percentage of construction costs for the past six years. Based on this analysis the agency proposes to use percentages for PE and CE as shown in **Figure 2-6** and **Figure 2-7**).

Work Type	Estimated Con Cost	M-Funded PE Phase	80th Percent.	Federal PE Phase
R&R	$0 - $6M	12%	15%	18%
R&R	$6M+	8%	10%	12%
CPM	$0-$2M	6%	8%	10%
CPM	$2M+	2%	3%	4%

Figure 2-6. Michigan DOT proposed preliminary engineering estimation table

Work Type	Estimated Con Cost	M-Funded PE Phase	80th Percent.	Federal PE Phase
R&R	$0 - $6M	12%	15%	18%
R&R	$6M+	8%	10%	12%
CPM	$0-$2M	6%	8%	10%
CPM	$2M+	2%	3%	4%

Figure 2-7. Michigan DOT proposed construction engineering estimation table

MnDOT uses parametric cost estimates based on historical data adjusted for a construction cost index. Contingency is added to account for variations in project cost and quantities. Consultants are sometimes hired on major projects to perform top-down or bottom-up estimates to validate MnDOT's estimates.

MnDOT divides projects into three levels for budgeting. Level 1 projects are the most costly and complex. These projects often have issues related to the environment and heavy engagement with stakeholders and the public. Level 2 projects have lower costs and complexity. Level 3 projects are those with the lowest complexity and cost.

MnDOT recently initiated a new process to set budgets for projects. Setting budgets for MnDOT Level 1 projects involves modeling considering uncertainty in cost, quantity, and risk. These budgets are established with a 70% probability the costs will be at or below the budget amount. MnDOT Level 2 and 3 budgets are set in the district considering the estimated cost, contingency, and risk. The cost of all three levels is inflated to the midpoint of construction. Budgets can be modified but the same process for setting the budgets must be used and additional scrutiny is typically applied.

ODOT has developed a cost estimating template and requires regions to use it to estimate the cost of all projects. The agency provides training and requires the staff performing cost estimates to be certified.

Initial estimates for PennDOT's larger projects are often provided by a study. Construction estimates are typically based on standard amounts for the asset (e.g., cost per square foot for a bridge type or cost per mile for road work). Estimates for the design phase is based on a percentage of the cost of construction. An amount for inflation is added to the estimate based on the year of expenditure. Estimates are updated at major milestones and at recurring intervals.

PennDOT's goal is to have at least 50% of projects let within 10% of the engineer's estimate and at least 75% let within 20% of the engineer's estimate. Each district engineer and consultants are rated on how close their estimates come to the engineer's estimate. Consultants are evaluated for future work based on their ability to meet the cost estimating goal.

Texas DOT (TxDOT) has components similar to those of Caltrans and WSDOT for estimating costs of projects. Allowances, risk-based contingencies, and escalation or inflation is added to the identified (base) cost and adjusted each year as it approaches final development for bidding. The TxDOT cost estimating website (TxDOT Construction Cost Estimating Guide[8]) provides information about and links to all the cost-estimating tools and guides, including the Construction Cost Estimating Guide used by the department.

TxDOT tracks estimates of PE, RW, utilities, final design, and CE but does not budget for total project costs. These development costs are based on a percentage of the cost of construction. TxDOT is developing a method to add a cost-estimating review and validation process as a separate step in its future process for project budgets.

UDOT uses several tools to develop cost estimates throughout the project development process. To begin, parametric estimates using historic costs adjusted for location and project type are used to provide project estimates for the long-range plan. As a project is moved to the STIP, a cost-estimating spreadsheet is used to provide a more consistent and in-depth estimate. At this point, estimates for project development are calculated based on percentages of estimated construction costs. Additionally, there is an effort to document risks and assumptions for later use.

Once a project is in design, UDOT uses two additional tools for estimating. The Aurigo Masterworks Cloud Platform[9] is UDOT's construction software, which contains historic construction costs and is used to develop the engineer's estimate. The UDOT Electronic Program Management[10] (ePM) system is the computer system that stores schedules (developed using Microsoft Project), budget numbers, and non-bid item costs, such as PE, environmental review and mitigation, RW, and CE (in-house and consultant costs). Information from ePM is transferred to Masterworks for further use. Additionally, ePM contains information used for consultant management.

VDOT recently conducted a study of its cost-estimating policies, procedures, tools, and training. One result from this study was the creation of a centralized Cost Estimation Office to improve the capability and consistency of cost estimating. This office recently publicized a Cost Estimating Manual[11].

8 Texas DOT Construction Cost Estimating Guide, https://ftp.dot.state.tx.us/pub/txdot-info/tpd/project-portfolio/estimating-guide.pdf

9 Aurigo Masterworks Cloud Platform, https://www.aurigo.com/masterworks-cloud-platform/

10 Electronic Program Management, https://udot.utah.gov/connect/business/business-applications/epm/

11 Virginia DOT Cost Estimating Manual, https://www.virginiadot.org/business/resources/Cost_Estimation_Office/VDOT_Cost_Estimating_Manual.pdf

VDOT's Project Cost Estimating System (PCES User Manual[12]) is used to generate and update cost estimates for projects that have been scoped. VDOT has several cost estimating tools that are used by project managers and estimators to assist in providing conceptual project estimates. One such tool is the Cost Estimating Workbook, which is a Microsoft Excel-based tool that VDOT staff, localities, and others use to submit project applications that includes estimates for projects, including PE, RW, and construction costs.

VDOT uses AASHTOWare Project Preconstruction™[13] software to refine estimates as the schedule gets closer to procurement. This software allows estimators to calculate costs using information similar to that used by contractors.

WSDOT's cost-estimating process has several steps, including a basis of estimate, development of a base estimate, a base estimate review, and development of a risk assessment. A graphic showing WSDOT's cost-estimating process is shown in **Figure 2-8**.

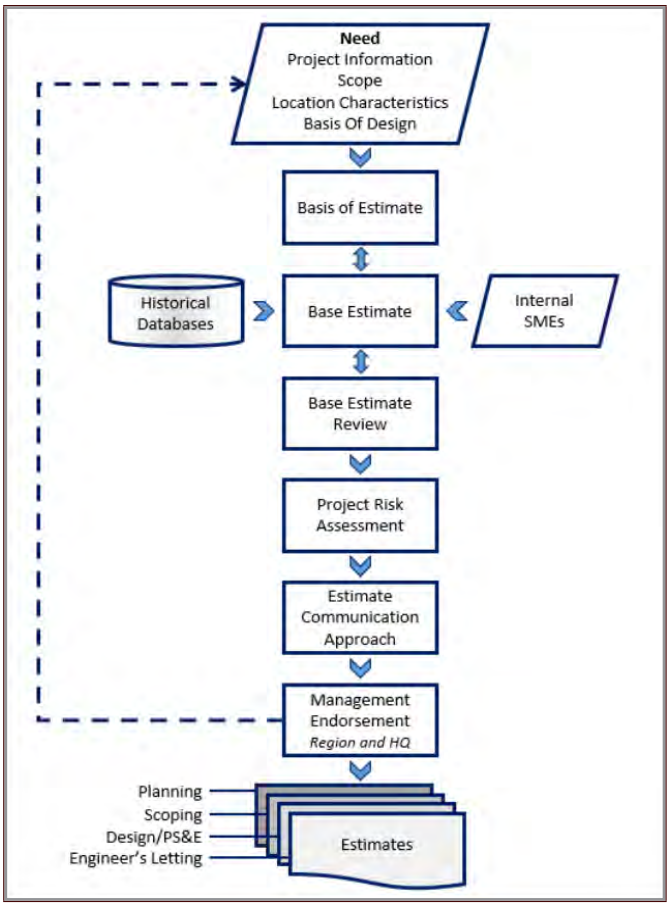


Figure 2-8. Washington State DOT cost-estimating process

WSDOT has developed tables that are used to estimate the costs of phases based on the type of program, cost, and work. A copy of a table showing the percentage to use for the PE phase is shown in **Figure 2-9**. A similar table is also available for CE estimates.

12 Virginia DOT PCES User Manual, https://www.virginiadot.org/business/resources/const/PCES.pdf

13 AASHTOWare Project Preconstruction™, https://www.aashtowareproject.org/apr-precon

Preservation Program PE as % of CN		P1 ROADWAY	P2 STRUCTURES		P3 OTHER FACILITIES				
Subprogram		PA	PB	PC	PD	PE	PF	PG	PH
		Paving Safety Restoration	Structure Preservation	Catastrophic Reduction	Rest Area	Unstable Slope	Weigh Station	Program Support	Major Drainage Electrical
$0	$ 500,000	25%	30%	40%	20%	25%	30%	20%	40%
$ 500,000	$ 1,000,000	17%	21%	28%	20%	25%	17%	17%	31%
$ 1,000,000	$ 2,000,000	14%	14%	24%	15%	15%	15%	14%	26%
$ 2,000,000	$ 5,000,000	9%	14%	14%	12%	12%	12%	9%	23%
$ 5,000,000	$ 10,000,000	5%	14%	15%	12%	11%	12%	5%	18%
$ 10,000,000	+++	3%	8%	14%	12%	3%	12%	3%	18%

Improvement Program PE as % of CN		I1 MOBILITY				I2 SAFETY			I3 ECONOMIC INITIATIVE			I4 ENVIRONMENTAL RETROFIT	
Subprogram		IA	IB	IC	IQ	ID	IE	IF	IG	IH	II	IK	IL
		Urban	Rural	Urban Bike Connection	HOV Lane	Collision Reduction	Collision Prevention	All-Weather Highway	Trunk System Completion	New Safety Rest Area	Bridge Restriction	Storm Water Runoff	Fish Barrier Removal
$ 0	$ 500,000	27%	23%	15%	33%	39%	30%	23%	30%	ND	ND	105%	65%
$ 500,000	$ 1,000,000	36%	23%	15%	30%	38%	30%	20%	30%	ND	ND	80%	59%
$ 1,000,000	$ 2,000,000	38%	23%	15%	30%	38%	15%	20%	25%	ND	ND	50%	43%
$ 2,000,000	$ 5,000,000	34%	20%	15%	25%	25%	12%	20%	25%	ND	ND	30%	29%
$ 5,000,000	$ 10,000,000	21%	20%	10%	20%	10%	10%	15%	20%	ND	ND	20%	17%
$ 10,000,000	+++	20%	16%	10%	15%	15%	15%	15%	15%	ND	ND	15%	11%

Figure 2-9. Washington State DOT preliminary engineering percentage estimate

WSDOT indicated that early estimates of the budget for PE are based on a historical percentage of the cost of construction; later, more detailed estimates are produced by the design team.

NDOT stated that a lesson learned, similar to the observation by CFL, is to focus efforts on estimating those 20% of items that make up 80% of costs (e.g., concrete, steel, and asphalt). Additionally, it was noted that the estimate of the base budget should not include an additional amount for risk or your concerns. That amount should be considered part of the risk component.

Finally, the increased use of design-build construction has resulted in challenges. To begin, it is difficult to apply bid history to design-build projects. The department must rely on the project developer to provide information regarding individual pay items. However, this is not typically part of the project, so it often does not get a high priority. Additionally, as more design-build projects are built there is less historic bid data that is available.

Risk

Several agencies have incorporated risk-based contingencies in project development estimates to quantify risks. This risk is in addition to the base cost and an amount for escalation or inflation.

Caltrans uses a scalable process to determine the type of required risk analysis based on the capital cost of the project, where higher capital costs require higher levels of quantified risk sophistication. Projects with lower capital costs may use qualitative risk analysis, while higher capital costs require either deterministic (Program Evaluation Review Technique) or probabilistic (Monte Carlo analysis) cost quantification. **Figure 2-10** shows the risk management requirements for Caltrans projects based on project type and cost.

Scalability Level	Project Capital Cost Estimate (Construction and R/W)	Risk Management Requirements
0	Minor B projects	None
1	Minor and Major projects within Minor A limits	Risk Register with qualitative risk analysis optional
2	Greater than Minor A limit to $75M	Risk Register with deterministic or probabilistic quantitative risk analysis
3	Greater than $75M	Risk Register with probabilistic quantitative risk analysis

Figure 2-10. Caltrans risk management requirements

Caltrans Project Risk Management Project Delivery Directive PDD09-R1[14] allows project managers, in consultation with the Project Development Team, to choose a higher or lower scalability level based on the project's complexity.

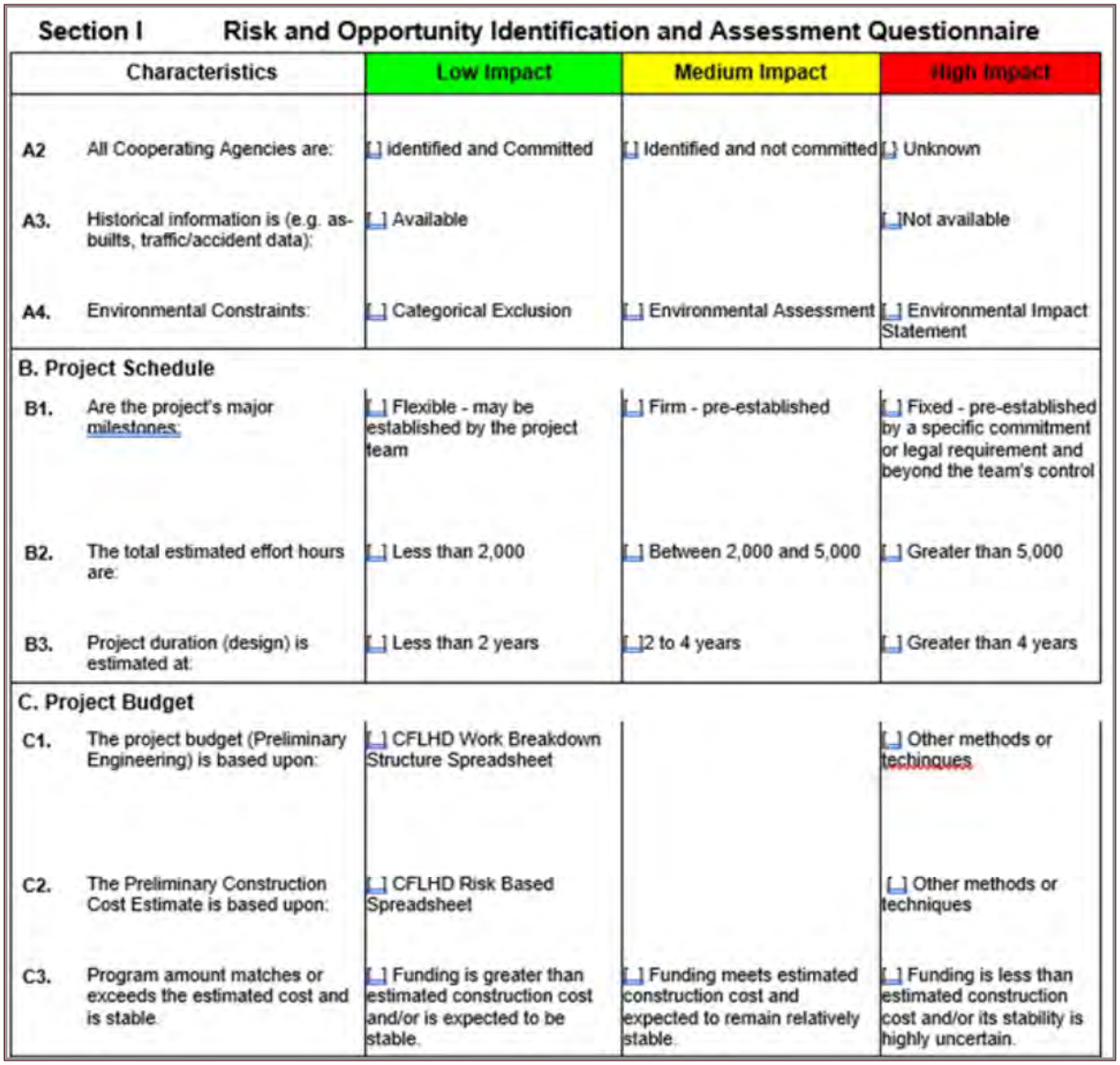
Caltrans has developed a user-friendly Microsoft Excel-based spreadsheet that is integrated with the risk model to estimate both support and capital risk costs. Caltrans is also currently beta testing a new quantitative risk tool that draws from and uploads data to a central database. The database will contain greatly enhanced risk-tracking capabilities that will allow the agency to share lessons learned, use historical risk data, and create risk reports. In addition, the tool will also include data fields that will allow for the management of risks at the portfolio and program levels.

Caltrans recently revised its Risk Management Handbook to assist in training new employees along with providing information on the operation of the risk tools. The manual also provides sections on lessons learned by function, frequently asked questions, and best practices dos and don'ts.

Additionally, Caltrans utilizes a Risk Register Certification form, which is a risk communication and control document that is signed by the project manager and project delivery deputies, or their delegates, at the end of a phase.

CFL uses a risk identification questionnaire that is a good facilitation tool to start a discussion regarding a project's risk characteristics (**Figure 2-11**). Other, more sophisticated tools are also used that require knowledge of risk management principles.

14 California DOT Project Delivery Directive PDD09-R1, https://dot.ca.gov/-/media/dot-media/programs/project-delivery/documents/pdd09_r1_1052020_mdk-a11y.pdf



Section I Risk and Opportunity Identification and Assessment Questionnaire

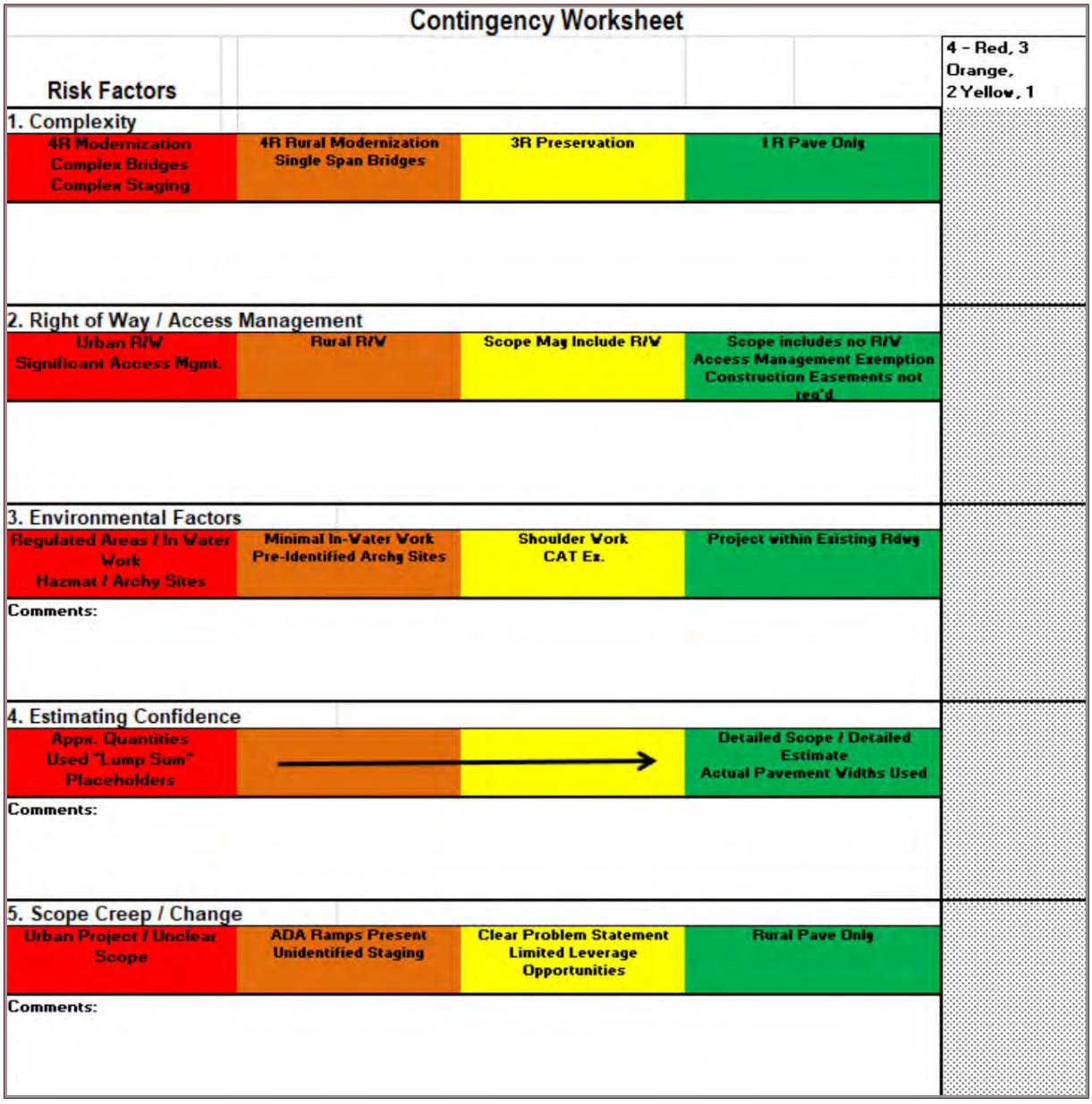
	Characteristics	Low Impact	Medium Impact	High Impact
A2	All Cooperating Agencies are:	[ ] identified and Committed	[ ] Identified and not committed	[ ] Unknown
A3.	Historical information is (e.g. as-builts, traffic/accident data):	[ ] Available		[ ]Not available
A4.	Environmental Constraints:	[ ] Categorical Exclusion	[ ] Environmental Assessment	[ ] Environmental Impact Statement
B. Project Schedule				
B1.	Are the project's major milestones:	[ ] Flexible - may be established by the project team	[ ] Firm - pre-established	[ ] Fixed - pre-established by a specific commitment or legal requirement and beyond the team's control
B2.	The total estimated effort hours are:	[ ] Less than 2,000	[ ] Between 2,000 and 5,000	[ ] Greater than 5,000
B3.	Project duration (design) is estimated at:	[ ] Less than 2 years	[ ]2 to 4 years	[ ] Greater than 4 years
C. Project Budget				
C1.	The project budget (Preliminary Engineering) is based upon:	[ ] CFLHD Work Breakdown Structure Spreadsheet		[ ] Other methods or techinques
C2.	The Preliminary Construction Cost Estimate is based upon:	[ ] CFLHD Risk Based Spreadsheet		[ ] Other methods or techniques
C3.	Program amount matches or exceeds the estimated cost and is stable.	[ ] Funding is greater than estimated construction cost and/or is expected to be stable.	[ ] Funding meets estimated construction cost and expected to remain relatively stable.	[ ] Funding is less than estimated construction cost and/or its stability is highly uncertain.

Figure 2-11. Central Federal Lands risk identification questionnaire

Following the assessment of risk, CFL assigns each risk to a responsible person. CFL uses a tool that provides documentation and tracking throughout the project lifecycle.

NDOT performs a Cost Risk Assessment (CRA) for its larger projects. A CRA is required for projects over $100 million in cost and is recommended if the estimated cost is between $25 million and $100 million. Additionally, NDOT has found it to be beneficial to perform CRAs early on, during planning or corridor studies, the National Environmental Policy Act process, and even during construction. NDOT uses Monte Carlo analysis to determine potential project cost and programs projects to the 70th percentile.

As a result of ODOT's Scoping Task Force, the agency modified its newly developed cost-estimating template to include risk tools. The regional office identifies characteristics of risk at the time the project is scoped. A risk contingency worksheet is used as part of the scoping process (see F**igure 2-12**). This provides a rough estimate of the risk contingency. Later, during design, a more complex probabilistic risk-based estimate replaces the contingency from the worksheet.



Contingency Worksheet

Risk Factors				4 - Red, 3 Orange, 2 Yellow, 1
1. Complexity				
4R Modernization Complex Bridges Complex Staging	4R Rural Modernization Single Span Bridges	3R Preservation	1R Pave Only	
2. Right of Way / Access Management				
Urban R/W Significant Access Mgmt.	Rural R/W	Scope May Include R/W	Scope includes no R/W Access Management Exemption Construction Easements not req'd	
3. Environmental Factors				
Regulated Areas / In Water Work Hazmat / Archy Sites	Minimal In-Water Work Pre-Identified Archy Sites	Shoulder Work CAT Ex.	Project within Existing Rdwy	
Comments:				
4. Estimating Confidence				
Appx. Quantities Used "Lump Sum" Placeholders	→	→	Detailed Scope / Detailed Estimate Actual Pavement Widths Used	
Comments:				
5. Scope Creep / Change				
Urban Project / Unclear Scope	ADA Ramps Present Unidentified Staging	Clear Problem Statement Limited Leverage Opportunities	Rural Pave Only	
Comments:				

Figure 2-12. Oregon DOT risk contingency worksheet

PennDOT evaluates risk throughout the scoping, design, and construction process. The procedures are contained in PennDOT's Design Manual[15] (September 2018 Change No. 3). It allows for improved estimates and schedules and more predictable cash flow. Risk is handled in a team approach with a risk manager for each project who oversees the process and risk owners who own individual risks.

TxDOT has a risk-based cost-estimating tool that is Microsoft Excel-based and is used to evaluate projects at each stage of development. TxDOT is moving toward an option to model risk with Monte Carlo analysis. The agency does not specify the probability of occurrence that districts must use in their estimates. Districts are allowed to manage their projects and set the level of probability and risk tolerance they will use.

15 PennDOT Design Manual, https://www.dot.state.pa.us/public/pubsforms/Publications/PUB 13M/September 2018 Change No. 3.pdf

UDOT performs a variety of risk assessments on projects. Qualitative assessments are performed for smaller projects to assist the Project Manager with an assessment of the largest risks. For large projects, a quantitative analysis is performed using Monte Carlo simulation.

WSDOT has a scalable process to determine the level of effort to be used for a cost risk assessment[16]. **Figure 2 -13** shows risk assessment requirements for WSDOT projects

WSDOT Cost Risk Assessment Requirements for Projects	
Project Size ($M)	**Required Process**
Less than $10M	Qualitative spreadsheet
$10M to $25M	Informal workshop using the WSDOT self-modeling spreadsheet
$25M to $100M	Cost Risk Assessment (CRA) workshop The scoping phase for these projects should include an informal workshop
Greater than $100M	Cost Estimate Validation Process (CEVP) workshop The scoping phase for these projects should include an informal workshop
Project Managers may use a higher-level process if desired	

Figure 2-13. Washington State DOT cost risk assessment requirements

Some agencies use risk contracts to develop a risk registry and risk schedule that can be used throughout the life of the project. These contracts provide an upfront assessment of risks for more complex projects and provide a second opinion to confirm or supplement an in-house view.

Agencies also conduct project cost risk workshops, where subject matter experts are invited to provide their expertise to evaluate the risk for specific projects. For TxDOT, these workshops are requested by the district managing the project; however, for large projects, a risk workshop is scheduled to complete a cost schedule risk assessment. WSDOT uses these workshops based on the size and cost of the project. Caltrans described how it documented lessons learned and the ways that anticipated risks were eliminated or mitigated during the closeout process. This was seen to be a valuable exercise that provided continuous improvement to the risk assessment process.

Dashboards

Several agencies explained how their use of dashboards to track estimates, budgets, expenditures, and schedules is an effective means of communicating project and program status to staff, leadership, and the public. These dashboards provide a representation to quickly identify if projects are on schedule and within budget. They are also helpful in tracking actual resource utilization compared to estimates.

Several of the dashboards presented were designed and built by agencies in-house and are not off-the-shelf products. Some agencies use Microsoft Excel-based spreadsheets, with which staff members are familiar. The dashboards, while functional, often are not efficient in sharing data with other programs.

16 Washington State DOT Cost Risk Assessment, https://wsdot.wa.gov/engineering-standards/project-management-training/project-management/cost-risk-assessment

MaineDOT developed a customized database dashboard (Maine DOT Public Map Viewer[17]) following its participation on an earlier NCHRP Domestic Scan. The dashboard was developed using Oracle Business Intelligence software that was adapted to MaineDOT's way of doing business. The dashboard provides access to all information related to a project. Tabs on the dashboard can be used to review the schedules and budgets of projects quickly. The dashboard is geographic information system-enabled so that a map showing the project is provided (see **Figure 2-14**).

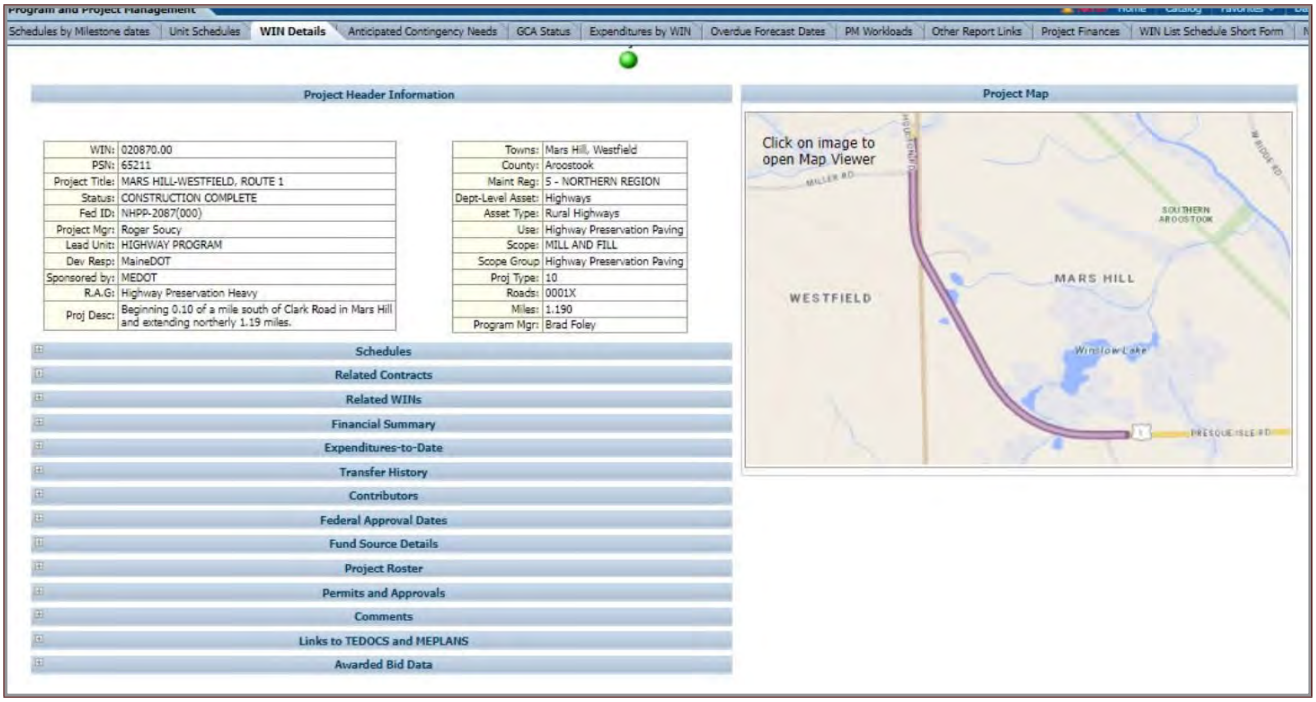


Figure 2-14. MaineDOT dashboard example

Through its Cost Estimating Dashboard, TxDOT has developed dashboards and reports to monitor cost estimates. **Figure 2-15** is a view of the statewide Cost Estimating Dashboard. This information can be filtered by district to provide reports that indicate the status of projects.

17 Maine DOT Public Map Viewer, https://www1.maine.gov/mdot/mapviewer/

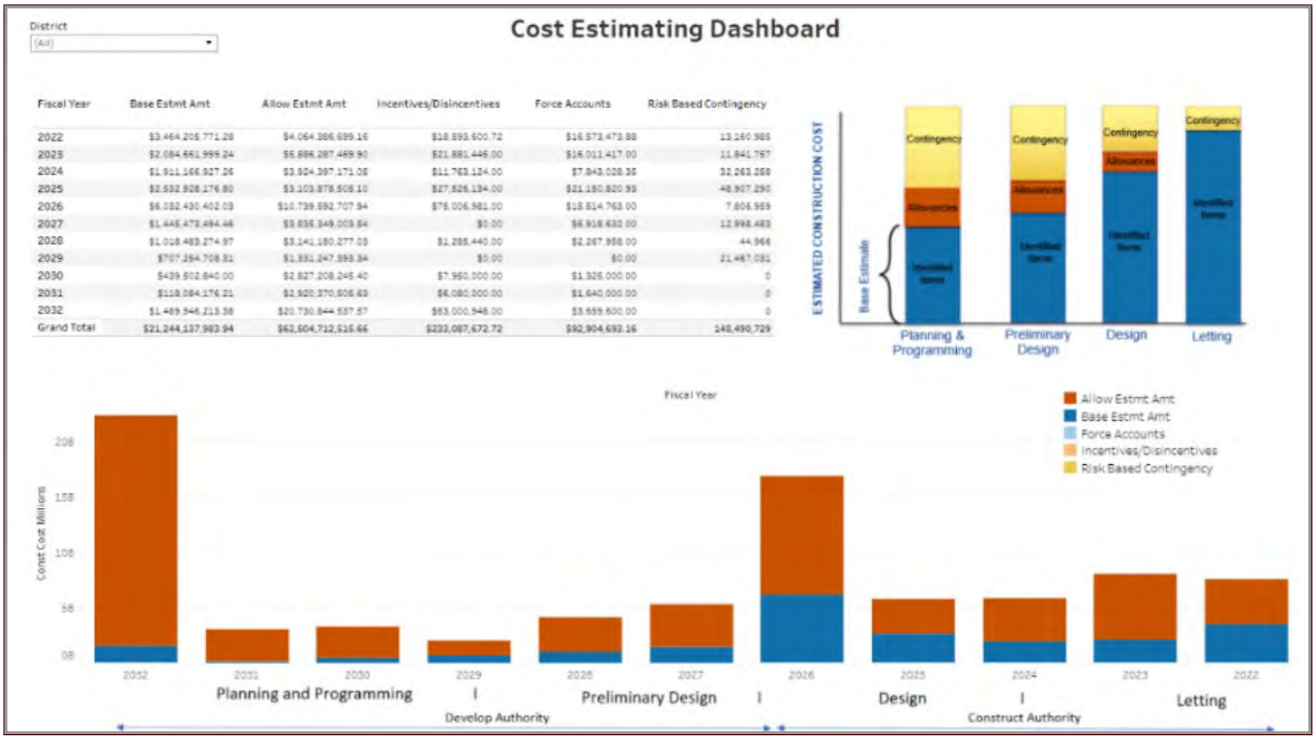


Figure 2-15. Texas DOT Cost Estimating Dashboard

UDOT has several reports on its dashboards. The Construction Management Estimate Report shows a summary of projects that are more than 10% over budget and also provides information on bid postponements by region. The UDOT Strategic Direction[18] website also provides information for management, including the project delivery status for project budgets and schedules.

The VDOT Projects Dashboard[19] provides information regarding the status of programs and projects. It quickly shows whether projects or programs are on time or on budget (**Figure 2-16**).

18 Utah DOT Strategic Direction, https://udot.utah.gov/strategic-direction/

19 Virginia DOT Projects dashboard, https://www.virginiadot.org/dashboard/projects.asp

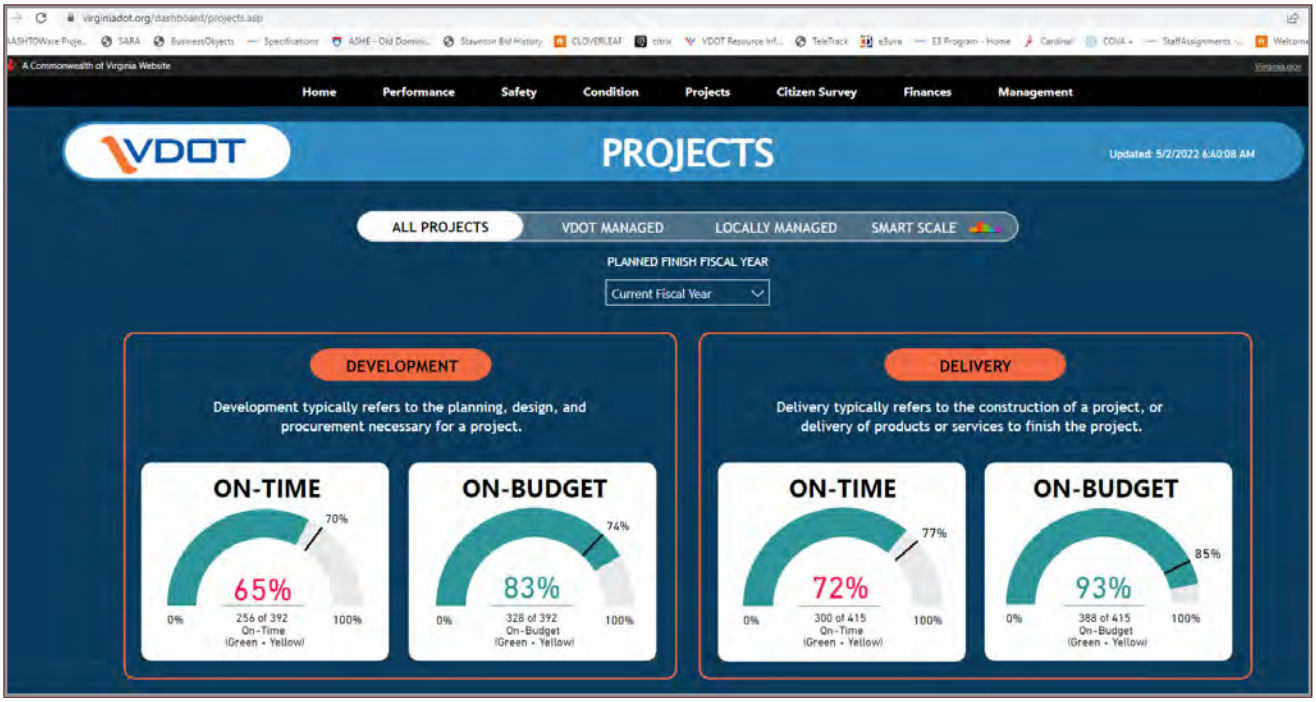


Figure 2-16. Virginia DOT dashboard

VDOT uses customized project schedule templates to guide staff regarding the required tasks for various types of projects (Project Tasks & Scheduling Guide: Project Development and Delivery Process[20]). The actual scheduling is done using Microsoft Project software. A project schedule is created that links tasks to phase dates using the template and scheduling software. This information is shared with the project programming system to keep track of the actual status of project development.

Tools and Data Systems

Most agencies have developed tools and data systems to aid in estimating and tracking project construction costs. Several have also documented procedures for estimating project development costs. As stated earlier, most agencies estimate project development cost based on percentages of the estimated cost of construction. Many of the tools and data systems used are based on Microsoft Excel and may not be efficient in sharing information ("talking" with other programs).

MaineDOT uses a customized database called ProjEx to track and report project estimates, budgets, and expenditures. ProjEx is integrated with the Work Plan management process that is used to maintain and monitor the status of projects.

GDOT uses Primavera P6 to schedule work on projects. Once a consultant begins work on a project, they are scored on how well they meet schedules. That information is used to evaluate these firms for future Statements of Qualifications.

A few agencies have developed templates to set expected schedules for phases of project development. NDOT is in the process of transitioning to use the Aurigo Masterworks Cloud Platform for estimating, budgeting, and scheduling projects.

20 Virginia DOT Project Tasks & Scheduling Guide: Project Development and Delivery Process, https://www.virginiadot.org/business/resources/Project_Tasks_and_Scheduling.pdf

ODOT uses AASHTOWare Project Estimation™ during design but not currently during scoping. The agency does plan to begin using it during scoping and throughout the development process to be consistent and identify trends and how estimates have changed during development.

PennDOT's Multi-modal Project Management System[21] is a database that maintains project delivery estimates and schedules. It is used to develop the STIP and project budgets through project delivery. **Figure 2-17** shows a screen that provides information on the actual approved costs over the lifetime of the project. It also provides information on the estimates for all phases of work.

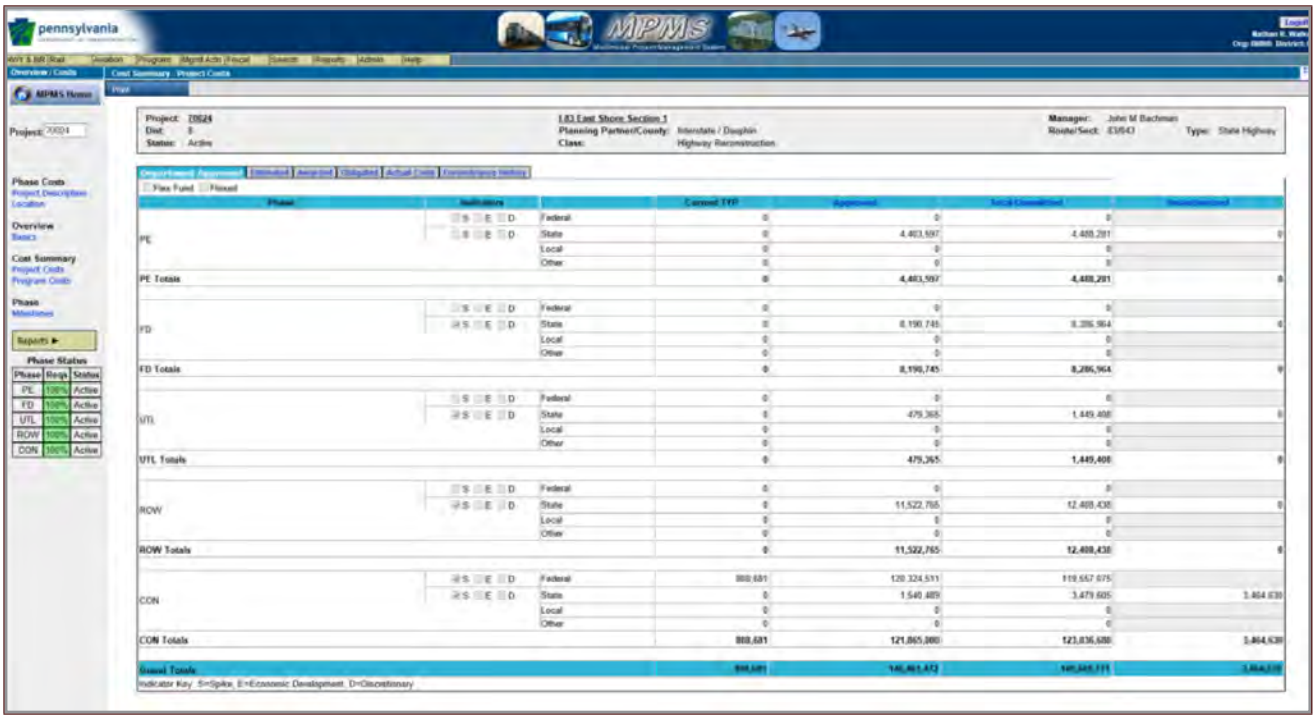


Figure 2-17. Pennsylvania DOT Multi-modal Project Management System overview – project cost

Additionally, PennDOT's Engineering and Construction Management System[22] is a powerful tool that is used for the construction bidding process to submit plans and special provisions to contractors. It is also used to analyze and accept bids. Because it has information on past bids it is also used to prepare and validate project estimates.

As part of its Modernize Portfolio and Project Management Initiative TxDOT has recently developed an integrated project management system called TxDOTCONNECT[23] that manages the delivery of transportation programs, projects, and RW. The system consolidates the functions of more than 40 outdated legacy systems, provides a user-friendly interface, automates key workflows, provides geospatial functionality, and numerous other benefits. TxDOTCONNECT provides a one-stop location for all project information, including estimates for project development phases.

21 PennDOT Multi-modal Project Management System, https://www.mpms.penndot.gov/MPMS/home.jsp

22 PennDOT Engineering and Construction Management System, https://www.ecms.penndot.gov/ECMS/

23 TxDOTCONNECT, https://www.txdot.gov/government/programs/mppm.html

UDOT has several tools that are used at various stages during the development of projects (Project Management & Project Delivery Tools[24]). One of these tools uses parametric analysis to estimate costs for the long-range plan. Before moving to the STIP, a concept development cost estimating spreadsheet is used to make a more in-depth cost estimate. Once a project is in the STIP, two other tools are used for budgeting and tracking. Masterworks is the construction software that contains information used to develop the engineer's estimate. ePM contains all budget information for projects, including all non bid item amounts such as PE, CE, and RW. Those amounts are then fed into the Masterworks program.

WSDOT is in the process of replacing its EBASE system, which is a database program used to record, store, and report estimates and bid history. EBASE documents all estimate updates, which can then be used as a basis for a new project. The EBASE system is being replaced with a more robust program that will share information with other programs through the life of a project.

Because many of these tools have been developed in-house and are often not integrated with other systems, several agencies are planning or are in the process of replacing or updating them. These situations require a great deal of effort and planning.

Contractor Involvement

Several of the presenters indicated that their agencies use former construction estimators or consultants to provide an independent construction cost estimate for some complex projects. These estimators typically use a bottom-up analysis based on production rates like that used by contractors bidding the work. This practice also typically provides an independent review of plans that considers the constructability of the project. Such analysis is not normally used on routine projects but is reserved for more complex projects or those projects with significant environmental or geotechnical issues.

Agencies also said that during rapidly changing market conditions there were challenges that impact project costs and availability of materials. For example, the presenter from WSDOT indicated that 93% of costs for materials, labor, and equipment had significantly increased year over year. In these situations, it can be helpful to establish communication with contractors and others familiar with current conditions and the availability of materials to avoid future problems with projects. UDOT has a statewide contract to hire these services from a group of former contractors. As a side benefit, UDOT mentioned that this support group also provides real time advanced notice or warning of problems regarding the availability or price increases of materials that might be needed for projects.

For Construction Manager at Risk projects, NDOT uses the contractor to work with its designers on the project while improving constructability and reducing cost. At the same time NDOT might also hire an independent cost estimator to provide a schedule to estimate working days and a bottom-up cost estimate. The estimates of the estimating engineer and the independent cost estimator are compared at milestones throughout the process. NDOT also uses this process to determine whether to put the project out for bid or to proceed with design-build.

24 Utah DOT Project Management & Project Delivery Tools, https://www.udot.utah.gov/connect/business/project-management-project-delivery-tools/

ODOT stated that having a more balanced portfolio of projects (i.e., a wide variety of project types utilizing more contractors) can be beneficial in reducing dramatic swings in unit costs for projects. Additionally, ODOT indicated that it has a process for engaging with individual contractors, one-on-one, to discuss the constructability of projects. These one-on-one meetings provide more-honest input than a meeting where other contractors are present. This process is structured to reduce the risk of violating competitive bidding requirements.

Communication

WSDOT pointed out the importance of considering estimates as a range. While efforts are made to consider all factors that can affect the cost of a project, it is not possible to know an exact figure until all the work is complete. Therefore, it is advisable to communicate estimates as a range to avoid leaving an implication of unwarranted accuracy. For establishing a budget number, WSDOT recommends using the risk modeling results, including the total project cost with project development costs inflated to the year of expenditure.

During the scan presentations the team witnessed different terms being used for the processes and procedures used during project development phases. This can cause confusion when dealing with partners, vendors, and stakeholders.

Finally, agencies pointed out the benefit of peer exchanges to share information, methods, and best practices. These peer exchanges can be internal to the agency or with partners, vendors, or sister agencies. For example, TxDOT conducts project management classes that introduce concepts and best practices for portfolio, program, and project management. These classes explain the importance of the concepts of project management and are taught statewide. TxDOT also has a community of practice that meets to provide support and resources for staff who are involved with construction cost estimating. Additionally, UDOT has a site called the Estimator's Corner that shares information regarding the local construction market, including large projects that are out for bid.

Miscellaneous

A couple agencies have begun using earned value (EV) for monitoring project budgets. Caltrans explained that EV is used as a flagging device that ties schedules and resources to identify issues before they become significant problems. Project managers are provided with quarterly reports that highlight issues with projects either falling behind schedule or running over budget so that corrective action can be taken.

CFL also uses EV to monitor and track the health of projects related to budget and schedule. An EV report calculates the health of the project based on calculations of the schedule performance index (illustrates if a project is ahead or behind planned schedule) and the cost performance index (illustrates if a project is ahead or behind planned budget).

In addition to EV, some of the agencies have invested time and effort to implement new methods and tools, including dashboards and bottom-up estimating as described earlier. It was stated that these methods and tools provide benefits but do require significant commitment or even major institutional change to be successful.

Another innovation that PennDOT discussed was its plans to invest in digital plan delivery using three-dimensional models. These models have the potential to provide more accurate quantities of earthwork that can improve the accuracy of cost estimates and budgets. Further, PennDOT is also investigating the use of four- and five-dimensional design models that can potentially improve scheduling and cash flow analysis.

Recommendations

The following are the scan team's recommendations based on the presentations and materials provided during the scan and finalized during a team meeting following completion of the presentations.

Scoping/Cost Estimating

- The use of standard templates, data systems, and tools for project scoping and cost estimating is a best practice that should be employed.
- It is recommended that manuals developed to guide the scoping process require a review of statewide plans and standards to ensure that project scopes are consistent with those documents.
- The use of an early PE phase as part of the development process prior to programming the construction phase is recommended for more-complex projects to identify issues early on, such as environmental risks and potential RW acquisition.
- The use of an owner's scope contract performed by a consultant to perform scoping and cost estimating can be beneficial in providing a different perspective and supplementing in-house resources.
- The use of former construction estimators or consultants with expert knowledge from a contractor's perspective to verify estimates and schedules and to review constructability can help provide a valuable second opinion.
- Sharing planning level tools for scoping and estimating with local agencies can improve their project proposals.
- Agency cost-estimating manuals and materials should be developed and updated regularly.
- The use of a flat percentage of construction costs for estimating the cost of project development and CE phases based on historic averages is an appropriate tool to use for typical non-complex projects with significant history.
- A uniform policy on escalation (e.g., inflating costs to the midpoint of a phase) is recommended to provide consistent guidance across all projects. (Training and guidance should be considered to assist project managers.)
- Cost-estimating programs and systems should capture history and assumptions for future reference. The basis of estimate should be updated at milestones, regular reviews, or annually, whichever comes first.
- Focus more attention on those 20% of bid items that result in up to 80% of costs or higher risk during scoping and project development.

Risk-Based Analysis

- Estimates and budgets should include risk-based contingencies to account for unknown and identified risks.
- Schedule risk analysis should be considered for high-profile and complex projects.
- Development of a robust risk-assessment approach that is scalable to total project cost and/or complexity is recommended.
- A project closeout process that documents lessons learned, actual resources used, and the effectiveness of the ways that anticipated risks were eliminated or mitigated is recommended.
- The use of a separate risk contract to evaluate risk and quantify outside factors that might impact the project's cost or schedule should be considered.

Budgeting/Tracking

- While the cost of construction is a major portion of project costs, the cost of project development is significant and should also be considered and budgeted.
- Dashboards and tools to budget and track project development costs in addition to construction costs will communicate progress to decision-makers and the public and assist agencies to identify actual resource needs to deliver the program.
- Project costs should be compared to planning estimates to identify problems early so that necessary action can be taken proactively.
- A change management process should be employed to aid in proactively managing project budgets and schedules that enable programming staff to better manage overall program budgets. An efficient change management process will keep project management focus on delivering the project and provide accountability and transparency.
- Implementation of EV analysis that provides regular reports and ties schedules and resources together can be beneficial in identifying potential problems early on.
- For work done by agency staff, it is important to establish a mindset of an owner-operator to effectively budget and track in-house project costs. It is important to strike a balance by acknowledging the differences between an owner-operator mindset, where staff tend to spend as much time as needed to deliver near-perfect products, and the need to work within established budgets.

Tools and Data Systems

- Programs and systems that "talk" to each other are beneficial in sharing information and saving historic data for future reference.
- It is important to consider technology costs, security of data, maintenance, and the quality of data.
- Updating and replacing legacy project development systems is important but costly and time consuming and should be done with significant planning and deliberation.

Communication

- Peer exchanges with transportation agencies and contractors to discuss project development and construction are beneficial and are encouraged.
- Consider a strategy for communicating the accuracy of project costs when releasing information on risk-based contingencies and cost estimates to avoid implying unwarranted accuracy.
- Agencies should define terms used in project development and be consistent when using them.

Implementation Strategy

The transportation community provides several opportunities at local, state, regional, national, and international meetings and conferences to share the findings and recommendations of this scan. In most cases these opportunities are regularly scheduled meetings. In other cases, new opportunities will arise as the situation warrants.

- Completed activities
  - Developed a Ready Results Brief to be shared at meetings
  - Routed the draft report to MnDOT upper staff for review and comments
  - Delivered a presentation to the AASHTO Committee on Design at its summer conference in Kansas City
  - Delivered a presentation of the draft report to the WSDOT Project Engineering Managers statewide meeting
  - Delivered a presentation to the TxDOT Community of Practice meeting
- Short-term activities
  - Presentations at scheduled meetings/conferences
    - National and International conferences
      - Future presentation at a Society of American Value Engineers conference
      - Future presentation at Cost Risk Estimating Management group
      - The RRB for the scan was distributed at the PIARC (World Road Association) conference on bridge inspections held in Madrid, Spain, in September 2022. The intent of the scan was shared at a very high level.
      - Future presentation at an AASHTO Committee on Project Management webinar
      - Presentation at the Transportation Estimators Association conference
  - State/regional meetings
    - Presentation to MnDOT district department management
    - Distribution of the final report to the MaineDOT Engineering Council to determine if further information is desired
    - Future presentation to the TxDOT Transportation Programs Division

        - Presentation at the TxDOT annual Short Course
        - Presentation to the MDOT Project Management Community of Learning
        - Presentation to the American Council of Engineering Companies group that meets with WSDOT staff
- Long-term activities
    - Develop and present a webinar on the scan findings and recommendations
    - Add scan findings and recommendations to training materials
    - Develop problem statements for future NCHRP research

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Appendix B: Scan Team Biographical Sketches

SCOTT A. PEDERSEN, PE (AASHTO Chair), has worked for the Minnesota DOT for 34 years. He is currently working as the program delivery engineer for the Metropolitan District. He graduated from the University of Minnesota with a bachelor's degree in civil engineering in 1996.

STEPHEN BODGE, PE, has been with the MaineDOT for over 20 years. He has held positions of highway designer, bridge designer, and project manager throughout his career. He is currently the assistant program manager for the Highway Program. He also serves on the AASHTO Committee on Design, the Technical Committee on Project Management, and the Technical Committee on Roadside Safety.

NICOLE CORONADO, PE, has over 13 years' transportation project and portfolio management experience. She started her career designing bridge structures has progressed to ultimately managing an $11 billion portfolio of transportation projects. She has a unique blend of project and portfolio management skills, including project planning and programming with an emphasis on risk and cost management and quantification of risks that can impact the planning, programming, and delivery of transportation projects for Texas DOT. Recently, Coronado led a Texas DOT Enterprise Work Group for Construction Cost Estimating to evaluate current cost estimating and business practices to bring consistency across the agency. She currently leads the first Texas DOT Construction Cost Estimating Community of Practice. She received a bachelor's degree in civil engineering from the University of Texas at Austin.

JASON GARZA, PE, has over 20 years of transportation project and portfolio management experience. He started his career in the private sector, performing road and utility design for various municipalities and road commissions. Since 2008, he has been an engineer at the Michigan DOT, where he has held roles in various work areas such as bridge program management, project management, construction, and road and bridge program management. In 2019, Garza became the Bay Region associate engineer for development and oversaw the road and bridge program, survey crew, bridge safety inspection, environmental permitting, real estate, and design work areas. He received a bachelor's degree in civil engineering from Michigan State University.

WENDY LONGLEY, PE, started her career in the private sector as a bridge engineer for URS and Finley McNary Engineering. In 2003, she began work for Central Federal Lands Highway Division as a bridge designer. From there, she's held positions of environmental compliance engineer, project manager and construction operations engineer and, most recently, as the project management branch chief of the Central Federal Lands.

DEAN R. MOON, PE, has been employed by the Washington State DOT for 32 years. He is responsible for project delivery support by ensuring designs are compliant with Federal Highway Administration and Washington State DOT policy. The primary responsibilities include providing policy interpretation and approval of variations from design policy through design analyses; leading statewide taskforce teams in the development of design policy; evaluating tort liability risk to the department through assessment of design decisions; and serving as the subject matter expert for risk assessments, value engineering studies, multidisciplinary teams, and design-build procurement teams.

ALBERT V. SHELBY III, is the director of Program Delivery at Georgia DOT. He is an Atlanta native who graduated from Southern Polytechnic State University with a degree in civil engineering technology. He began his career at the Georgia DOT in 1998. During his career, Shelby has served in the Office of Urban Design as a design engineer and design group manager and in the Office of Program Delivery as a senior project manager, assistant office head, and office head. He is currently the director of Program Delivery.

CARMEN E. L. SWANWICK, PE, is the Utah DOT project development director. In the last few years, she has served as the Region Two deputy director, the director for Construction, and the project development deputy director. She also served as the Utah DOT chief structural engineer for almost 10 years. Swanwick has over 15 years of experience as a consultant in structural engineering within the transportation industry. She received both her bachelor's and master's degrees from the University of Utah in civil/structural engineering. She chairs the AASHTO Committee on Bridges and Structures and served six years as the chair of the AASHTO Committee on Bridges and Structures T-4 Committee on Construction. Swanwick participates in numerous National Cooperative Highway Research Program projects and Transportation Research Board Committees. She has been involved in several Utah DOT initiatives through the years, including the accelerated bridge construction program, development of the unmanned aerial systems program and, recently, the digital delivery effort with an emphasis on building information modeling for bridges and structures.

DENNIS R. SLIMMER (Subject Matter Expert) retired from the Kansas DOT in 2015 after serving 45 years in the agency. In his final assignment he was the bureau chief of Transportation Planning, where he oversaw units responsible for traffic data collection, mapping/geographic information system, freight/rail, public transit, bike/pedestrian, metropolitan planning, corridor management, and geographic and data reporting. During his career he served as a design engineer in the Bridge Section, estimating engineer in Headquarters Construction, construction engineer for the Topeka office of District One, and congressional liaison for Kansas DOT. He earned a bachelor's degree in civil engineering from Kansas State University and an MBA from Washburn University.

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Appendix D: Amplifying Questions

Domestic Scan 21-03
Successful Approaches to Setting Project Development Budgets
Amplifying Questions

Domestic Scan 21-03 is being conducted to investigate how budgets are determined for activities occurring during a project's development phase, including the National Environmental Policy Act clearance process, surveys, preliminary traffic studies, preliminary engineering design, plan preparation, project management, site investigation, right-of-way acquisition, utility relocation, and public engagement, in addition to budgeting for expenditures related to the actual construction of the project. The objective of the scan is to document the experiences of leading agencies and identify best practices that can be adopted and applied by other agencies to improve budget development practices. Your answers to the following questions, plus any supporting documents, will be of great importance to the work of the scan team.

1. Agency size and organization
    a. What is the average annual program budget of your agency (including federal, state, and local funding)?
    b. What is the range in construction value for projects? What would be considered an average value for a project?
    c. Which units within your department are responsible for project estimates and budgeting?
    d. What percentage of your program is handled internally versus by others?
    e. Please share an organization chart.
2. Program and project budgeting
    a. Does your agency have a formalized policy guiding the establishment and management of project budgets? If so, can you please share your policy?
    b. Are there specific programs or tools used in the establishment and management of project budgets (e.g., AASHTOWare)?
    c. Are project budgets developed as a model of project cost, risk, and inflation or is the project team provided with a budgeted number and the project development is to fit the budget?
    d. How is inflation administered for the establishment of project budgets? Do you have a procedure to account for significant increases in the cost of specific materials (e.g., asphalt, cement, and structural steel)?
    e. If you are establishing budgets based upon total project cost, how are you modeling the elements for preliminary engineering, post-letting costs, and construction engineering?
        i. A percentage of the estimated project costs

ii. Based upon expenditures from previous projects of similar scope and scale

iii. Other

f. Do you have a formal established process to review and adjust budgets? Is there a threshold upon which adjustments are implemented? Please briefly describe and include any guidance used.

g. Is the same process used to establish and maintain project budgets for all projects in your program, or are different processes used based on project type, size, dollar value, or complexity?

h. What have been your observations since the implementation of your current system to establish and maintain project budgets?

i. Project scopes are more clearly defined early in the process

ii. Project scope is managed throughout the process

iii. Project change has been reduced as a result

iv. Other

i. How has your process evolved since the initial implementation of the establishment and maintenance of project budgets?

j. What are the benefits you see based upon the establishment and maintenance of project budgets?

k. Have you made any recent changes to your processes based on experience? Do you plan to make any changes in the near future?

l. As you have modified your budgeting processes what barriers did you experience? What lessons have you learned?

3. Estimation

a. What types of estimates are developed to assist with the establishment of project budgets?

i. Parametric (bid-based prices or historic data of similar projects)

ii. Contractor-style estimates (top down or bottom up)

iii. Other

b. How does your agency estimate costs at different stages of a project? Planning stage? At preliminary engineering milestones (30%, 60%, 90%, construction ready)?

c. Are there specific tools or software programs that are used to establish and manage project cost estimates?

i. AASHTOWare

ii. Proprietary software

iii. Agency-built software

iv. Spreadsheets

v. Other

d. How are estimates documented? Do you require a basis of estimate document? Does your estimating system build on previous estimates as they are generated?

e. How do you model project risk into the profile to establish project budgets? At what stage(s) of a project is risk assessed?

f. What methodologies do you use to model project cost and project risk to assist in the establishment of project budgets?

i. Monte Carlo Analysis

ii. Other

g. Do you establish project budgets based upon a specified level of probability of occurrence?

h. What have been the lessons learned regarding the estimation of costs, risk assessment, and modeling the relationship between cost and risk? How has this evolved?

i. Is the method of cost estimation prescribed or are different methodologies allowed?

j. Are independent cost estimators or consultants used or required to validate project cost estimates?

4. Trends in project budgets:

a. Since the time you have been establishing project budgets, have you noticed trends in the overall cost of delivering projects, such as:

i. Added project outreach and engagement?

ii. Added requirements for project documentation?

iii. Other?

b. Has project delivery method affected the accuracy of estimates (e.g., design-build, design-bid-build, construction manager-general contractor)? Has the loss of bid history from design-build projects affected your ability to obtain bid data for estimating? In what way?

c. Does your agency retain bid history for reference and use in estimating? How is it utilized?

5. Performance measures

a. What performance measures are used to track the accuracy of project development and total project cost estimates and budgets? What experience have you had regarding the accuracy of

project development and total project cost estimates and budgets?

   b. Are processes in place to take corrective action if there are significant deviations from the actual estimates and budgets for project development and total project cost?

6. Legislation and regulations

   a. Are there legislative mandates or regulations that affect your ability to estimate or budget project development and total project costs? If so, please discuss.

7. Sustainability

   a. Is there a department or group responsible for continuous maintenance and improvement for project estimation and budget development?

   b. What training is provided to staff preparing estimates and budgets?

   c. Are resources made available to support systems and personnel responsible for project estimation and budgeting?

8. Other information

   a. Is there anything else you would like to share with the scan team?