Improving Early Phase Cost Estimation and Risk Assessment: A Department of Transportation Case Study

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ABSTRACT

Early cost estimation, especially cost escalation, has become a major challenge for State Highway Agencies (SHAs). Cost overruns reduce the accuracy level of the construction cost estimate and cause conflict between owners, project managers, and contractors. To address this problem, a case study DOT was selected to evaluate and improve existing scoping, cost estimation and risk assessment processes.

At first, this study identifies nationwide current best scoping, cost estimation and risk assessment practices during early stages of the project. Later, through a series of interviews with some of the case study Department of Transportation (DOT) Districts, the current scoping, cost estimation and risk assessment practices implemented by this DOT staff were identified. The results were compared to those practices identified in national research documents and best practices at other DOT’s. Further, a gap analysis comparing this SHA’s current practices to national ideal practices revealed the areas of possible further improvement as risk assessment, review and approval of estimates and estimate documentation. Through pilot studies on three projects from the case study Districts the effectiveness of the improvement recommendations were assessed. Based on the evaluation of the pilot studies many of the recommendations proved to have notable impact on the performance of the case study DOT’s project scope definition, cost estimates, and risk assessments. The final recommendations are in five areas of cost estimating, documentation, risk assessment and contingency calculation, executive policy and general issues. Depending on the area of concern, recommendations have three levels of policies/practices, processes/tools, and resources.

Keywords: Early Cost Estimation, Risk assessment, Documentation, Policies and Practices, Contingency Calculation
INTRODUCTION
Early estimation of the cost of highway projects has become a major challenge for SHAs. Over the life of highway projects which can easily exceed several years, cost escalation is known as one of the main criteria that reduces the accuracy level of the construction cost estimate (1) and became a source of friction between owners (especially government owners), project managers, and contractors in terms of project cost variation subsequent to the owner’s decision to build (2).

Cost increase over the course of project development and delivery is caused by many factors such as insufficient information on project scope, inadequate knowledge of project risks over the project life cycle and unforeseen project complexities. Project cost increases can affect the performance level of both SHAs and project stakeholders. This escalation can also diminish the ability of SHA to properly distribute agency funding and stakeholders to deliver projects within the budget (3).

In this work, a case study DOT was selected to evaluate and improve existing scoping, cost estimation and risk assessment processes. Other DOTs may find these recommendations useful in assessing and improving their processes related to scoping, cost estimating and risk assessment.

OBJECTIVES
An objective of this paper is to identify nationwide current best scoping, cost estimation and risk assessment practices during early stages of the project. Moreover, this paper focuses on a gap analysis between the same best practices and the existing case study DOT scoping, cost estimation and risk assessment methods. Based on the mentioned analysis, it is aimed to improve processes of scoping, cost estimation and risk assessment in the national and possibly international SHAs.

LITERATURE REVIEW
Early cost estimates are critical to the initial decision-making process of complex construction projects. According to Burke (4), at each phase in the project life cycle, different levels of cost-estimating accuracy can be achieved based on the detail of information available. In particular, early cost estimates at the planning and programming phase have a typical accuracy range of ±25 percent. Even at this level of accuracy, early cost estimates enable the comparison of different design alternatives at the predesign phase and the selection of the most economical technical solution. At the same time, appropriate financing procedures can be elaborated upon at an early stage of project implementation. As such, it is important to arrive at reliable early cost-estimating figures (5).

An element of uncertainty is inherent in any construction cost estimate. To account for a practical amount of uncertainty, project teams should use some method of risk identification and analysis to estimate contingency amounts to be included in the project estimate. These uncertainties, risks, and associated contingencies should be incorporated into estimates during each phase of project development (6). The extent of risk analysis on any given project is determined by its development phase, level of complexity, size, and other such project-specific characteristics.
Project complexity significantly influences the methods and tools an estimator uses to prepare and manage project cost estimates. Project complexity is also used to identify proper risk management techniques. Recognition of project complexity through a formal definition results in a classification of project complexity that can be applied to all projects. Three levels of complexity are considered as follows: 1) Non-Complex Projects; 2) Moderately Complex Projects; and 3) Most Complex Projects. By determining the complexity of the project it is possible to define the type of risk analysis (7).

Risk management is a specialized area of research and practice in all of the construction industry. The on-going application of the risk management process, is often the factor that determines if a project is successful or not by a number of performance measures.

For the purposes of this paper, identifying, assessing, and mitigation plans for a project’s risks are the most important items as they relate directly to the developing a project estimate. Once the uncertainties and risks associated with a project are identified, the probability of them occurring and magnitude of impact can be assessed whereby contingencies can be placed within the estimate to account for them. Contingencies are estimated costs associated with particular risks that are then added to the base estimate (i.e., cost of known items) of the project. It is expected that those contingencies remain with the estimated project and are expended during the project development and construction phases through the continuing risk management process.

STUDY METHODOLOGY
In this paper, the following five-step methodology was followed to provide constructive recommendations for DOTs addressing their problem relative to project scoping, cost estimating and risk assessment.

- Identify national level best practices
- Understand and describe the DOT’s current practices
- Perform a gap analysis by comparing national best practices to DOT current practices
- Conduct pilot test development and deployment of best practices
- Make evaluation and recommendations for improving DOT practice

Best Practices Processes, Techniques and Tools
Review of the available resources demonstrated that the best practice should cover three components adequately. These three components are cost estimate processes and sub-processes, cost estimate techniques and cost estimate tools to help to implement the processes. Comprehensive content analysis of the mentioned resources determined that National Cooperative Highway Research Program (NCHRP) Report 574 and Mn/DOT Cost Estimation and Cost Management Technical Reference Manual (TRM) (8) provide the most rational frameworks and the required means to encompass the essential components. Therefore, it was concluded that practices introduced by these two documents are the closest to national level best practices in the areas of scoping, cost estimating and risk assessment.
A good understanding of the elements of the best practices is essential for better identification of gaps in the DOT’s processes and providing recommendations for further improvements. As shown in Figure 1, the identified best practice cost estimation and risk assessment process has a generic structure with five sequential steps. These steps are as following:

1. Determine Estimate Basis
2. Prepare Base Estimate
3. Determine Risk and Set Contingency
4. Review and Approve Estimate
5. Determine Estimate Communication Approach

**FIGURE 1 Planning & Programming Cost Estimation and Risk Assessment Process**

1. **DATA COLLECTION AND CASE STUDY**

Identifying the Case Study DOT Current Practices

Identifying “how” an estimate for a project is built is the second step in determining the gap between the best and current practices. Scoping, cost estimation, and risk assessment data were
collected through interviewing the case study DOT’s Districts and by comparing their input with national best practices.

Knowing which estimating approach to use often depends on where in the project development life cycle a given project lies and also the complexity of the project. Although the nomenclature used to identify the various project phases differ slightly between state departments of transportation, the progression through the phases remains the same. As it is shown in Table 1, the case study DOT is standardizing the terminology used to identify their project development phases.

**TABLE 1 Description of The Case Study Project Phases**

<table>
<thead>
<tr>
<th>Planning &amp; Programming</th>
<th>Preliminary Engineering</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-range planning</td>
<td>~4 years out from letting with approximately 20–30% of design completed</td>
<td>From 20–30% design to full PS&amp;E of letting</td>
</tr>
<tr>
<td>Advanced planning</td>
<td>~4 years out from letting with approximately 20–30% of design completed</td>
<td>From 20–30% design to full PS&amp;E of letting</td>
</tr>
</tbody>
</table>

**Survey of the Case Study DOT’s Districts**

Collaboration with the case study DOT working group members was built to identify how this DOT produces scopes, estimates, and risk assessments, and to document the processes currently used. The working group members represented a broad cross-section of functions within this DOT at the District and division levels; therefore, the knowledge and experience of these DOT personnel generated a reasonably defined process for how this DOT currently prepares project scopes, estimates, and risk assessments for highway and bridge projects. The data was gathered through interviews in four different Districts. During these interviews, the District staff was asked how frequently they performed scoping, cost estimation and risk assessment functions for a “moderately complex project” in relation to the steps previously presented (see Figure 1).

**Results of the Surveys**

During the course of the interviews with the Districts, it became evident that the case study DOT staff often struggled with quantifying their frequency of use of the cost estimation and risk assessment processes and sub-processes. Their dilemma was mostly the result of the lack of formality in performing certain tasks. For example, identifying risks would be conducted by the design engineer but not in any specific or structured method for any particular project. Such informal and unsystematic approaches may or may not result in documented items that could be found in a project file or estimate worksheet. As the interviews transpired, the researchers attempted to note where possible when the case study DOT performed a step or sub-process but did so on an informal basis.

This DOT staff indicated that the project itself, its size and level of complexity, often dictated whether processes and tasks were performed formally or informally. Researchers attempted to
normalize the responses by asking this DOT staff to consider their answers based on a moderately sized, moderately complex project.

2. GAP ANALYSIS
   Calculating the Performance Gaps
   After the four District interviews, the collected data was analyzed and the results were compared to the best practices identified in the NCHRP Report 574 and refined by the Minnesota DOT research (3,8) and reflected in Figure 1. The gap analysis was used to identify areas where agency-wide improvements could be made. During interviews, the case study DOT staff was requested to indicate the frequency level of specific actions with a one of five frequency of response. The qualitative responses were converted to numerical values based on the conversion shown in Table 2 to conduct the gap analysis.

   **TABLE 2 Conversion of Interview Responses**
<table>
<thead>
<tr>
<th>Frequency of Use Response</th>
<th>Equivalent Percentage Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always</td>
<td>100%</td>
</tr>
<tr>
<td>Frequently</td>
<td>75%</td>
</tr>
<tr>
<td>Sometimes</td>
<td>50%</td>
</tr>
<tr>
<td>Infrequently</td>
<td>25%</td>
</tr>
<tr>
<td>Never</td>
<td>0%</td>
</tr>
</tbody>
</table>

   Once the interview responses were converted to a percentage, it was then possible to determine an average response for the four Districts by using standard calculations. The resulting “case study DOT average” was compared against the identified best practices which were considered to be the “ideal” or national best practice frequency use value of 100 percent (i.e., always performed).

   Since the main focus during the interviews was on the first two project phases (i.e., Planning and Programming and Preliminary Engineering), the gap analysis results only for these two project phases are presented in this paper. Figures 2 and 3 illustrate the case study DOT’s performance on each of the cost estimation sub-processes and show the gaps between the current performance and ideal best practices from national research. In these two figures, gaps in cost estimation and risk assessment processes and sub-processes are illustrated in three colors based on their frequency of use.

   **Gap Analysis Results**
   Once the gap analysis was completed by comparing the case study DOT’s current practices to those identified as best practices visual representation of the results were generated. The results are shown in Figure 2 and Figure 3 for Planning and Programming Phase and Preliminary Engineering Phase respectively. In these figures the activities that were frequently performed by the case study DOT staff, are presented as white boxes. Similarly the activities that were sometimes fulfilled by the staff are depicted as light gray boxes and infrequent activities as dark gray boxes.
Upon inspection of the gap analysis results shown in Figures 2 and Figure 3 areas for further improvement were identified. Risk and contingency determination, review and approval of cost estimates and documentation were the areas that the case study DOT District’s use was consistent with national level best practices.

**FIGURE 2** Gap Analysis Results for the Planning & Programming Project Phase
3. PILOT TEST STUDIES

The third step of this research project was initiated by applying the results of the gap analysis to the development of pilot test materials and tools. The researchers initially focused on the area where they believed the greatest amount of improvement could be achieved: risk identification, risk assessment, and contingency setting. Full-day workshops were held with two DOT Districts to pilot test tools and techniques associated with project risk determination. Each District selected a project that they currently had in early development and the researchers guided each District through a series of presentations and exercises to help them determine the specific risks associated
with their respective projects and calculate contingencies to be carried in the project estimate to account for the unknowns and/or uncertainties revealed through the risk identification process. To address the other two areas identified for DOT improvement – estimate documentation and estimate review and approval, the researchers developed workshop modules that presented tools and techniques to test in each area. This effort created workshop materials based on existing research (2, 3, 8) covering the three areas for improving DOT’s construction estimates:

Module 1 – Estimate Documentation
Module 2 – Risk Identification, Risk Assessment, and Contingency Setting
Module 3 – Estimate Review and Approval

Later, the research team decided to focus on both selection of the Districts and development of pilot test approach simultaneously. For this purpose, the case study DOT directors introduced three Districts as potential candidates for the implementation process. While the approach to this workshop was developed, the research team has shifted their focus to the development of best practice materials to be implemented in the pilot workshops. The team decided to implement the process on a District’s proposed project to enhance the learning process for the participants. For this purpose, the research team asked the suggested District directors of transportation planning and development to select a project and then provide project information such as cost estimation data and project drawings, descriptions of the project, and other related information.

To optimize the process, DOT staff was asked to select projects that were closer to the letting time, such as within one or two years, which means that participants have more familiarity with the earlier phases of that specific project. After the development of pilot test materials which mainly include forms, handouts, templates, guides, and bullet lists from previous research (2, 3, 8), the research team members decided to start with the second Module for this process and change/improve the modules based on the feedback which the first two Districts provided at the end of their half-day workshops. After each workshop, evaluation forms were distributed to collect participants’ opinions to modify the process and change any of the proposed tools. Later, research team members refined some of the utilized tools and developed new materials to best fit the case study DOT cost estimation and risk management activities.

The research team then conducted a two-day comprehensive workshop with new materials in two of selected Districts. At the end of the mentioned workshops, participants were asked to implement the cost estimation and risk assessment process to their selected District project in a three week time period. Following this period, an interview was conducted with two Districts’ members, District directors of transportation planning and development and the case study DOT team to gain a better understanding of the effectiveness of the proposed tools and techniques in the implementation process.

Pilot Test Materials
When participants became familiar with the workshop objectives, gap analysis and other introductory information, a very short and brief project description, project map and summarized estimated cost were presented. Then, project estimators, planners and engineers were asked to provide more information about the method of cost estimation and risk assessment.

In this phase of the research project, the team introduced the tools and techniques which can improve cost estimation and risk assessment process during early project phases. Table 3 shows the tools and techniques which were presented in the case study DOT pilot test workshops.

**TABLE 3 Cost Estimation and Risk Assessment Tools and Techniques (2, 3, 8)**

<table>
<thead>
<tr>
<th>Documentation</th>
<th>Risk and Contingency</th>
<th>Review and Approve</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Summary of Key Project Definitions</td>
<td>1. Recognition of Complexity</td>
<td>1. Recognition of Complexity</td>
</tr>
<tr>
<td>4. Project Estimate File</td>
<td>4. Assumption Analysis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Risk Statement</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6. P x I Matrix</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7. Contingency Percentage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8. Expected Value</td>
<td></td>
</tr>
</tbody>
</table>

4. **PROPOSED RECOMMENDED IMPROVEMENTS**

DOTs are examining ways to create consistent, accurate, and well-documented project scopes, cost estimates, and risk assessments at the various project phases for roadway and bridge construction projects. Based on the gap analysis and pilot test implementation of this research project, further improvements were identified and several recommendations were made. These recommendations are depicted in the matrix in Table 4. Upon inspection of this matrix five areas of possible improvement were identified:

- Cost Estimation
- Documentation
- Risk Management
- Executive Policy
- General

Improvement actions for each area were recommended at three different levels:

1. Policy/Practice,
2. Processes/Tools and
3. Resources.

It is suggested that other DOTs may find these recommendations useful in assessing and improving their processes related to scoping, cost estimating and risk assessment.

**Table 4 Cost Estimation and Risk Assessment Recommendations Matrix**
### Practice/Policies:

#### 1. Cost Estimating
- **Review & Approve All Cost Estimates**
- **Grow and Maintain Agency Culture recognizing Importance and Role of Cost Estimating**
- **Require a Cost Estimate Baseline**
- **Develop Cost Estimating Manual**
- **Determine Desired Estimating Processes and Products**
- **Develop Tools and Guidance for Cost Estimating**
- **Train Staff and Implement Cost Estimating Tools**
- **Develop “Cost Estimator” Career path**
- **Train Staff and Implement a Project Estimate File for All Projects**

#### Risk Assessment and Contingency Calculation
- **Grow and Maintain Agency Culture recognizing Importance and Role of Risk Management**
- **Test Reminder of Risk Management Process**
- **Train Staff and Implement Risk Management Tools**
- **Train Staff and Implement Risk Management**

#### Executive Policy
- **Decide What Processes to Standardize, Recommend and/or Require**
- **Formalize Required Cost Estimation Processes in Policy**
- **Integrate Scope, Cost Estimating, Schedule and Risk Management**
- **Develop Performance Measures for Cost Management**

#### General
- **Develop and Implement Cost Management Practice**
- **Move to Total Project Cost Management**
- **Develop Sources of Risk Management Expertise (In-House/Outside)**

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The purpose of the Review and Approve Cost Estimate is to:

1. Ensure that the estimate is as complete and accurate as possible based on the project’s definition and characteristics and;
2. Obtain District Management acceptance and buy-in of the total project cost that will become the baseline for managing cost during design.

This study suggests that DOTs need to define a policy which formalizes the review and approval process. Although it has been seen that informal cost estimate review and approval process is a common practice in some DOT Districts, but the formalized practice could have a substantial effect on the accountability of DOT’s staff.
• **Grow and Maintain Agency Culture recognizing Importance and Role of Cost Estimating**

Based on this study, it is recommended that DOT staff needs to gain a better understanding of cost estimation importance. In this regard, DOTs could invest in creating an agency-wide culture which recognizes the importance and role of cost estimating. It is suggested that the process of creating such a culture can be initiated through informative workshops/training.

The potential benefits of this effort include improved delivery of projects and program management, better use of available resources, greater credibility with the public and other stakeholders, and increased satisfaction as a result of more efficiently and effectively meeting public needs.

• **Require a Cost Estimate Baseline**

Cost estimation and risk assessment research project highlighted that DOT Districts need to emphasize on the importance of setting and documenting project baseline. Therefore, it is recommended that DOTs define a policy that directs DOT staff to formally prepare a project cost estimate baseline. This policy responds to DOT management’s vision of department-wide priority on managing and controlling costs, achieving statewide uniformity and consistency in cost estimation, and establishing clear accountability for managing costs.

2. **Documentation**

• **Require Documentation of All Estimates**

This study clarified that DOTs need to define a policy which formalizes the documentation process. Most case study DOT Districts stated that since documentation requires considerable time and effort, most personnel ignore the importance of a formal documentation process. Therefore, this DOT frequently encounters major problems to discover the reason/assumption for any of the earlier decisions.

This policy responds to DOT management’s vision of achieving statewide uniformity and consistency through improved documentation. To that end, it is recommended a clearly documented Total Project Cost Estimate be prepared in each phase of project development. The Total Project Cost Estimate covers construction, design, right-of-way, utilities, construction engineering and contingency. This documentation serves to communicate project and cost information, both internally and externally. Proper estimate documentation enables reviews and approvals by District management before the cost estimate is released to external stakeholders.

3. **Risk Assessment and Contingency Calculation**

• **Grow and Maintain Agency Culture Recognizing Importance and Role of Risk Management**

It is recommended that DOTs emphasize the importance and role of risk management. This study revealed that risk management process is not implemented in all case study DOT projects regularly. However, the lack of implementation of formal risk assessment and management can
cause inaccurate contingency calculation and eventually inaccurate total project cost estimates. Therefore, it is suggested that DOTs define a statewide policy which elaborates on the importance and impact of risk management through a series of training workshops. This policy responds to DOT management’s vision of achieving reliable and accurate estimates and statewide uniformity and consistency of project cost estimates.

4. Executive Policy

- Decide What Processes to Standardize, Recommend and/or Require

Once the processes that would help to improve the cost estimates and risk assessments are defined it should be decided to what extent a DOT wants to require their implementation throughout the agency. Decision making in this regard has several choices. The agency may wish to just introduce and recommend the process to the Districts and leave the implementation decision to the Districts themselves. For some processes the agency may see the need for agency-wide implementation, for instance the processes that consistency in the outputs among Districts is vital. For these types of processes the agency may wish to standardize the process and require the Districts to implement them. The decision of what processes to standardize, recommend or require depends on two factors. The first factor is that if the outcome of the processes has any impact on the decisions made out of the District such as the amount of the funding of the project. The second factor is the extent of the impact of the process on project performance.

- Formalize Required Cost Estimation Processes in Policy

The agency executives should decide what processes should be formalized and set the policies to support them. The research team identified three areas that the processes should be formalized. These areas are estimate review and approval, estimate documentation and contingency assessment. These three areas were revealed to have major effect on the cost estimates and risk analysis. However, the case study DOT Districts did not implement these processes completely or if they did implement then, they were performed informally. In the contingency discussion it should be defined when the contingency may be used, and if it is not used who is the owner of the remaining amount.

5. General

- Develop and Implement Cost management Practice

Project cost management will start with management of the project’s definition and apply to every project including projects funded from set-asides. It is recommended DOTs develop cost management process models which identify all the existing and desired functions and sub-functions relevant to their DOT cost estimation and cost management process and integrate the desired cost estimation and cost management functions within the pre-construction phases of their DOT project development process.

- Move to Total Project Cost Management
The research team believes that DOT central offices need to define a policy which obligates District directors to move to total project cost management. For statewide consistency, all project-related costs should be expressed as a Total Project Cost Estimate in year-of-construction dollars, regardless of the project development phase. The Total Project Cost Estimate consists of a base estimate and a contingency. Post-letting or construction contingency is included, but separately identified, to account for potential supplemental agreements, change orders, cost overruns, or incentive awards, as applicable.

**Process/Tools:**

1. **Cost Estimating**
   - **Develop Cost Estimating Manual**
     It is recommended DOTs develop a state wide standard cost estimating manual providing step by step guidelines to ensure consistency of cost estimation procedures and to facilitate the project review and approval process.

   The purpose of development of DOT Cost Estimating Reference Manual is to assist DOTs in achieving accuracy, accountability, and consistency in cost estimation and cost management efforts during the Planning, Programming, Design, and Letting phases of project development. This Manual should address a wide range of topics that include broad policies and organizational issues to detailed estimating tools. That being said, the majority of this Manual should be written with junior estimators as the focus. Senior management personnel will find this Manual more useful as a review or reference document. More experienced estimators should find this Manual useful in creating estimating checklists or as a process review checklist.

   - **Determine Desired Estimating Processes and Products**
     DOTs should define what cost estimation processes and products wish to develop and implement. The first step of this process is to develop the processes that help to attain the agency policies. One source of identifying the desired practices is through review of the state of practice and determining the best national and other DOTs best practices.

   - **Develop Tools and Guidance for Cost Estimating**
     Based on the feedback gathered after pilot test implementation in the selected case study DOT Districts, utilizing the cost estimation and risk assessment proposed tools can effectively contribute to contingency calculation accuracy, preparation time and consistency of cost estimation process.

   Therefore, it is recommended that DOTs develop, integrate processes and tools for cost estimation, management, and control and incorporate application and consistent statewide use of well-documented cost estimation processes and tools.

2. **Documentation**
   - **Develop Tools and Guidance**
Documentation is one of the areas that has major impact on the overall quality of the cost estimates. It is recommended DOT's develop tools and guidance to support documentation and help the Districts better document their cost estimates.

3. Risk Assessment and Contingency Calculation
   - Apply Risk Management Process
     Risk management process which consists of risk identification, assessment, allocation and control, is an important part of project management. It is recommended DOT central offices organize state wide workshops to instruct staff on risk management and also to implement the steps of the process on District current projects.

   - Develop Tools and Information for Setting Contingency
     Accuracy of contingency calculation has a substantial impact on the overall quality of cost estimate which affects the quality of DOT's funding distribution. Development of tools and processes for contingency calculation improves the accuracy level of contingency calculation. It is recommended DOT's develop contingency calculation tools and how to implement guidance.

4. General
   - Integrate Scope, Cost Estimating, Schedule and Risk Management
     Scope definition, cost estimation, managing the schedule and risk management are all components of the project management process. These components have interactions and affect each other. Therefore, DOTs should have holistic view toward these components of the project management process. It should be noted that discussing cost estimation without considering schedule or risk management is inadequate.

   - Develop Performance Measures for Cost Management
     During the follow up session with case study DOT District directors, it was revealed that development of performance measures for cost management allows Districts to improve the overall cost estimation quality. During various points in the project development or once the project is complete, performance measures can be derived from comparison of target values designated during project development and the achieved value measured after project completion. It is recommended DOT's develop an agency-wide performance measures process for cost management that leads to improved cost quality.

Resources:
1. Cost Estimating
   - Train Staff and Implement Cost Estimating Tools
     It is suggested DOT central offices to organize state wide cost estimation and risk assessment workshops to educate DOT personnel to implement best practices in cost estimating process. It is worth noting that use of the cost estimating tools and techniques improve the cost estimation and risk assessment practices.
Cost estimation involves the use of resources, including personnel that have the necessary knowledge, skills, and abilities to accurately and consistently predict costs. Depending on the project phase, the primary responsibility for cost estimation will reside with either the concerned District or the Central Office. The role of the Central Office would primarily be to provide cost estimating direction, support, and resources, including training opportunities, to DOT Districts.

- **Develop “Cost Estimator” Career path**

Cost estimation process, tools and techniques required for enhancing cost estimation accuracy depends on the experience and expertise of human resources. Developing “Cost Estimator” as a career path in DOT organizations should improve the project development process.

DOT District Estimators would play a key role in ensuring reliable and accurate estimates and tracking estimate evolution throughout project development. By residing in the Districts, the Estimators will have close contact with the local stakeholders.

Key functions of the District Cost Estimators should be as follows:

- Estimate involvement throughout project development (Planning to Letting)
- Lead project estimates with focus on estimate pricing
- Estimate appropriate items
- Coordinate input from Functional Groups
- Maintain estimate files
- Define risk and contingency amounts
- Communicate estimates

2. **Documentation**

- **Train Staff and Implement a Project Estimate File for All Projects**

It is suggested DOTs highlight the importance of cost estimation documentation and provide the necessary resources for this purpose. The research team believes that documentation tools such as Project Estimate File can be used as a major documentation resource in all DOT projects.

A Project Estimate File should be established and maintained for the life of the project, from Planning to Letting. The basis of the estimate and the inputs to cost estimating should be documented every time a cost estimate is updated.

3. **Risk Assessment and Contingency Calculation**

- **Train Staff and Implement Risk Management Tools**

Since risk identification and assessment has a substantial impact on the quality of project cost estimating, it is recommended DOTs to organize state wide workshops/training sessions to educate implementation of risk management tools and techniques.

- **Develop Sources of Risk Management Expertise (In-House/Outside)**
The research team believes that DOTs need to develop sources of risk management expertise to aid in identifying, assessing and controlling potential project risks. Depending on the project type, size and complexity DOTs may need to utilize in-house risk management expertise and/or hire a risk management consulting firm.

Risk management is concerned with future events, whose outcomes are unknown, and how to deal with uncertainties by identifying and examining a range of possible outcomes. The objective is to (a) understand risks and (b) mitigate or control risks. Understanding the risks inherent with each potential project alternative is important to controlling cost and developing estimates that reflect the cost of accepted risks and risks transferred to the contractor. Risk management and an understanding of project uncertainty should assist estimators in setting appropriate contingencies for each individual project. This understanding is also important to managers of estimation processes. Cost estimation is one tool in a comprehensive risk management process.

**CONCLUSIONS**
As DOTs examine ways to create consistent, accurate, and well-documented project scopes, cost estimates, and risk assessments at the various project phases for roadway and bridge construction projects, this paper identified three areas where the agency could make some initial changes to implement best practices recognized in national research. Those areas of project development where the initial focus of improvements should start include:

- Scope and estimate documentation,
- Risk determination and contingency setting, and
- Estimate review and approval.

After the series of workshop to pilot the use of various tools and techniques to address these three areas of project development, feedback from the Districts who participated in the workshops aided the researchers in formulating conclusions and recommendations. Based on interactions and observations with the case study DOT as well as direct experience with other state departments of transportation (DOT’s), the recommendations to meet the objectives of this study are summarized in Table 4 - Matrix of Project Development Recommendations.

The recommendations are categorized into five areas: cost estimating, documentation, risk assessment and contingency calculation, executive policy, and general items. Across these five areas, the recommendations fall into three broad functional categories: practices and policies, processes and tools, and resources. After the resulting matrix of topic areas and functional groups, each recommendation shown in Table 4 is expanded with further explanation and details.
REFERENCES


