Development of Contingency Factors for Construction, Right-of-Way, and Utility Costs

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16. Abstract
This research effort is part of a collaborative research project between the North Carolina Department of Transportation (NCDOT) and North Carolina State University's (NCSU's) Institute for Transportation Research and Education. This project was undertaken to investigate potential improvements and additions to the current risk assessment efforts of the NCDOT, with a focus on assessing contingency percentages for construction, right-of-way (ROW), and utility relocations. Specifically, this research project aims to assess contingency allowances to be potentially used in the project planning process for construction, ROW, and utility relocation cost estimations. In addition, methods that other state DOTs use to address inflation were investigated, particularly as they pertain to the State Transportation Improvement Program (STIP) process. The methodology includes a literature review, survey of state DOTs regarding their contingency and reserve allowances and inflation practices, review of the NCDOT's estimating process, validation of current contingency allowances, and recommendations. The literature review and survey results indicate that most DOTs apply contingency allowances to their project estimates during the early project development stage and maintain some level of contingency allowance at the plans, specifications, and estimate (PS&E) stage. Most DOTs include management reserve as part of contingency or do not consider it at all. Also, most state DOTs include inflation of the project cost in the project estimates to the time of bid letting or year of expenditure. The NCDOT accounts for inflation in a unique way compared to the other state agencies who responded to the survey; the NCDOT reserves a portion of available funds for programming the STIP to account for inflation. This approach reflects a 'funding side' approach as opposed to a 'project cost side' approach to managing project portfolios. With a project cost approach, inflation is included in each cost estimate. The survey results indicate that inflation needs to be considered carefully in the estimating process. The current estimating process at the NCDOT applies different contingency allowances to each of the three major project components, i.e., construction, ROW, and utility relocations. Project cost data, including estimates, bid amounts, and actual costs, were used in this study to validate the current contingency allowances. The results show that the current contingency allowances appear to be reasonable, as contingency is concerned, as they cover known risks with uncertain outcomes, also referred to as 'known-unknowns' (e.g., actual utility relocation cost and schedule). These risk items typically are identified in a risk register, such as the NCDOT's Risk Assessment Worksheet. If the NCDOT were to adopt a project cost model, then a management reserve allowance would be recommended as an addition to each estimate. According to the Association for the Advancement of Cost Engineering, management reserve is "an amount added to an estimate to allow for discretionary management purposes outside the defined scope of the project, or otherwise estimated. May include amounts that are within the defined scope, but for which management does not want to fund as contingency or that cannot be effectively managed using contingency." Essentially, management reserve covers unknown-unknown events (e.g., making a significant scope change during the design phase). For this research project, the NCSU research team developed reserve allowances for construction, ROW, and utility relocation. Because more data were provided for construction (compared to ROW and utility relocation), the reserve allowances could be determined by project type for each estimate stage and for the bid amount. Reserve allowances were determined for only Stage I ROW and utility relocation costs due to data unavailability for the other stages. Recommendations are provided to assist the NCDOT in modifying its current estimating process (if a project cost model is of interest) that would include adding costs for both inflation and management reserve to the NCDOT's current project estimates. This effort also would include investigating ways to improve data accuracy and facilitate the tracking of planned and actual project costs.

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Executive Summary

This report details the research project that was conducted by researchers at North Carolina State University (NCSU) under the sponsorship of the North Carolina Department of Transportation (NCDOT). This research project was undertaken to investigate potential improvements and additions to the current risk assessment efforts of the NCDOT, with a focus on contingency factors for each of the three main components of a project: construction, right-of-way (ROW), and utility relocations. Specifically, the goal of this research project is to develop and recommend contingency allowances for use in the project planning process for construction, ROW, and utility relocation cost estimations. In addition, methods that other state DOTs use to address inflation were investigated, particularly as they pertain to the State Transportation Improvement Program (STIP) process. The methodology employed in this project involves a five-step process:

1. Conduct a literature review of project contingency and reserve allowances and inflation.
2. Survey state DOTs to understand ways they address contingency and reserve issues in construction, ROW, utility estimates, and inflation in the STIP process.
3. Review the NCDOT's estimating process, with a focus on contingency allowances.
4. Validate current NCDOT contingency factors using cost data from completed projects.
5. Provide recommendations to improve the NCDOT's estimating practices.

The literature review showed that state DOTs estimate project costs differently depending on the methodology they use to determine contingency and address inflation. Most DOTs apply contingency to their project estimates during the early project development stage and maintain some level of contingency at the plans, specifications, and estimate (PS&E) stage. The method used to determine contingency allowances also varies by state DOT and project characteristics. For example, some DOTs use risk-based estimating approaches to determine contingency allowances for larger, more complex projects. Other approaches involve using only one contingency allowance for the entire project or separate allowances for each component (e.g., roadways, structures, and utilities). Most DOTs include management reserve as part of contingency or do not consider management reserve at all. Inflation is generally considered in the estimates to the bid letting date.

The current estimating process at the NCDOT applies contingency allowances to each of the three major project components, i.e., construction (~85% of total project cost), ROW (~11% of total project cost), and utility relocation (~5% of total project cost). The construction estimates employ different contingency allowances, called miscellaneous and mobilization factors (referred to as 'Misc & Mob') for roadway, structure, and construction utility costs. These Misc & Mob costs decrease from the feasibility study phase (Stage I) to the final PS&E stage (Stage IV). Engineering costs for design and inspection include a 3% to 5% contingency allowance. The NCDOT Utilities Unit recently began adding a 25% contingency allowance to project utility agreements to cover the possibility of higher utility costs and extra work not generally covered, such as tree removal and erosion control. The NCDOT ROW Unit applies either a 1.7 or 1.9 multiplier to its land acquisition cost estimates to cover the possibility of higher land purchase and condemnation costs.

The main insight gleaned from the contingency analyses of the three major project components is that the current contingency allowances appear to be reasonable *as contingency*, which typically covers known risks with uncertain outcomes, also referred to as 'known-unknowns' (e.g., the actual utility relocation cost and schedule). These risk items typically are identified in a risk register such as the NCDOT Risk Assessment Worksheet. Under the current 'funding side' model, the NCDOT reserves a portion of available funds for programming the STIP to account for inflation as well as project overruns, thereby effectively reducing the amount of funds available for other projects. If the NCDOT were to adopt a 'project cost side' funding model, then each estimate would provide a more accurate representation of the final project cost, from the feasibility estimate (Stage I) to PS&E (Stage IV), because the estimate would include inflation (to the bid date or year of expenditure), contingency, and management reserve. Management reserve is:

> *. . . .an amount added to an estimate to allow for discretionary management purposes outside the defined scope of the project, or otherwise estimated. This may include amounts that are within the defined scope, but for which management does not want to fund as contingency or that cannot be effectively managed using contingency. Synonyms include: Reserve and Reserve Allowance* (ASCE 2007).

Essentially, management reserve covers unknown events whose outcomes are uncertain, i.e., unknown-unknowns (e.g., making a significant scope change during the design phase or adding additional signage outside of the contract work area during the construction phase).

The NCSU research team developed management reserve allowances for construction, ROW, and utility relocation. Because more data were provided for construction compared to ROW and utility relocation, the construction reserve allowances could be determined by project type for each estimate stage and for the bid amount. Reserve allowances were determined for ROW and utility relocation costs for Stage I only due to data unavailability for the other three stages. Exhibits 1 and 2 provide summaries of the recommended reserve allowances for construction and for ROW and utility relocation costs, respectively. Note that these reserve allowances do not include inflation.

Construction Estimate Reserve (added to base and contingency costs)	**Bridge Projects**		**All Other Projects***
	≤$1 million	**>$1 million**	
Stage I	0%	35%	30%
Stage II	0%	25%	25%
Stage III	0%	15%	20%
Stage IV	0%	0%	5%

*Includes rural, urban, interstate, and highway safety projects.

Construction Project Type	N	Construction Phase Bid Reserve (add to Bid Amount)
Bridge Projects (≤$5 million)	150	0%
Bridge Projects (>$5 million)	142	5%
Rural	42	5%
Urban	43	10%
Interstate	33	15%
Highway Safety	17	10%
All Others (except bridge projects)	N/A	10%

Exhibit 1. Management Reserve Allowances for Construction Costs

Right-of-Way Estimate Reserve (added to base plus contingency)	All Bridge Projects	All Other Projects*
Stage I	85%	60%
Stage II	No data	No data
Stage III	No data	No data
Stage IV	No data	No data

*Includes rural, urban, interstate and highway safety projects.

Utility Relocation Estimate Reserve (added to base plus contingency)	All Bridge Projects	All Other Projects**
Stage I	0%*	65%***
Stage II	No data	No data
Stage III	No data	No data
Stage IV	No data	No data

*Adding 25% contingency is sufficient; no reserve amount necessary.
**Includes rural, urban, interstate, and highway safety projects.
***Based on limited data (12 projects).

Exhibit 2. Management Reserve Allowances for Right-of-Way and Utility Relocation Costs

The state-of-practice for applying inflation factors in the STIP process also was investigated in this study. This part of the research project was based on a three-part online survey of state transportation agencies conducted by the NCSU research team. Appendix A presents the surveys. Fifteen states (including North Carolina) responded to the request for information, which included two topics of interest in terms of applying inflation factors: available revenue and project costs. With regard to available revenue, five states assume that revenues will increase, one state (North Carolina) reserves a portion of the available funds for programming the STIP to account for inflation, three states have mixed assumptions regarding revenue (such as applying a reduction factor as a conservative approach), and the remaining six states do not directly address revenue inflation in their STIP process. With regard to project costs, 15 states (including North Carolina) assume that project costs will increase.

Recommendations for changing from a 'funding side' model to a 'project cost side' model for funding NCDOT project costs are as follows:

- **Inflation**
    - Carefully consider inflation in the estimating process. Most state DOTs include inflation of the project cost in their project estimates to the time of bid letting.
    - Forecast inflation for individual projects using a cost index, such as the Construction Cost Index (CCI) published by the Engineering News-Record (ENR).
        - For construction projects, adjust the estimate to the predicted project's acceptance date or to the year of expenditure.
        - For ROW and utility relocation projects, adjust the estimate to the predicted project letting date.
- **Management Reserve**
    - Adopt the management reserve allowances shown in Exhibits 1 and 2. Collect additional project data for Stages II to IV for ROW and utility relocation in order to determine those reserve allowances. Show reserve amounts as a separate line item in each estimate.
- **Contingency Reporting**
    - Report base estimates and contingencies separately to make it easier for project managers to assess the risks found in the Risk Assessment Worksheet and ensure that sufficient contingency factors are included in the estimates.
- **Data Management**
    - Investigate ways to improve data accuracy and facilitate the tracking of planned and actual project costs. For example, for utility relocations, NCDOT could consider collecting data on additional costs (e.g., tree removal and erosion control) and compare them to the 25% contingency allowance that is currently being applied to utility relocation agreements.
    - Consider setting up a project cost dashboard to collect and disseminate project data from the early feasibility phase (Stage I) of a project through completion (Stage IV), the bidding phase, and project closeout. Having quick access to these data can provide useful insights for improving future project performance.
- **Estimate Performance Assessment**
    - Reevaluate the contingency allowances and reserve allowances periodically and adjust the numbers, considering factors such as project size and location.

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Introduction

For this research project, the North Carolina State University (NCSU) research team investigated possible improvements and additions to the current risk assessment efforts of the North Carolina Department of Transportation (NCDOT), with focus on contingency allowances for construction, right-of-way (ROW), and utility relocations, which are the three main NCDOT project components. Inflation also is addressed as it pertains to the State Transportation Improvement Program (STIP) process. Contingency allowances are an important component of risk assessment and, if not assessed properly, can lead to cost overruns. A previous Technical Assistance Request (TAR-2019-14) research project conducted by the co-principal investigator analyzed nine state DOTs with robust risk assessment programs and reviewed the literature that pertains to risk management programs to provide a state-of-practice document for the NCDOT (Jaselskis and Perez 2019). Furthermore, a current research project (RP-2021-16) is underway to investigate improvements to and expansion of the NCDOT's current risk assessment program (which is under the purview of the NCDOT Value Management Office) and to incorporate the program into the NCDOT's new integrated project delivery process.

Research Objectives

The primary goal of this research project is to validate the contingency allowances currently used in the NCDOT's project planning process for construction, ROW, and utility relocation cost estimations. In addition, inflation and ways that inflation is addressed during the STIP project phase are investigated to determine inflation's role in cost estimations. Another objective is to provide recommendations to the NCDOT regarding project contingency allowances and inflation considerations.

Research Approach

The research team established a five-step research approach to provide insights to the NCDOT regarding the use of contingency factors and inflation factors for project cost estimates during the preconstruction phase, beginning with the feasibility estimate (Stage I) through to the final plans, specifications, and estimate (PS&E) stage (Stage IV). Exhibit 3 schematically presents the five-step approach, followed by a description of each associated task.

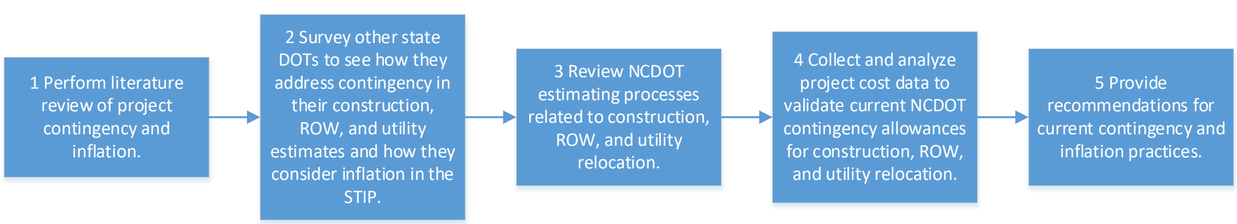


Exhibit 3. Research Methodology

Task 1. Perform a literature review to determine ways that other state transportation agencies address contingencies in their project estimates. Include topics that relate to inflation and ways that DOTs address purchasing power over time in their STIP process.

Task 2. Survey state DOTs to learn about their practices with regard to contingency and inflation.

The survey that was conducted for this task was guided by a review of earlier synthesis efforts that the NCSU research team has undertaken. The scope and timeline of this project did not allow for a thorough synthesis of practices, but the research team nonetheless was able to identify high-level procedures used in other states. The research team worked with NCDOT personnel to distribute the online survey through the American Association of State Highway and Transportation Officials (AASHTO) to solicit information about other states' application of contingency factors and their risk management/cost estimation processes as these efforts relate to this research project. Three different versions of the survey were used, one for each of the three main project components (construction, ROW, and utility relocation); refer to Appendices A.1, A.2, and A.3, respectively. Before sending out the surveys, the research team first tried to identify the most suitable contact person(s) within the DOTs. Each of the three surveys contained the following sections:

- Section A. Respondent Information
- Section B. General Cost Estimating Practices
- Section C. Project Risk Quantification (Contingency)

In addition to the contingency-related surveys, the research team also contacted subject-matter experts at other state DOTs to understand ways they account for changes in purchasing power over time in their STIP process.

Task 3. Understand the NCDOT's estimating process, including its use of contingency and inflation factors, by conducting a thorough review of NCDOT processes related to the estimation of construction, ROW, and utility relocation costs throughout the project life-cycle. This information is essential for understanding the timeline, inputs, and variables associated with the respective estimation processes.

Task 4. Collect and analyze project cost data provided by the NCDOT that reflect each of the main estimation components along with their respective contingency factors: construction (roadway, structures, construction utilities, and engineering), ROW, and utility relocation. Use this data to validate or improve the current NCDOT contingency factors.

Task 5. Provide recommendations to the NCDOT to improve its current estimating practices.

Literature Review and State-of-Practice Review

Risk management processes vary across state DOTs according to a recent synthesis study (Jaselskis and Perez 2019). Although practices vary among the different state DOTs, for the most part, all the risk management programs resemble those described in the Project Management Body of Knowledge (PMBOK). This literature review is relevant to the proposed research project because it provides useful ideas and concepts that can readily be adopted by the NCDOT as it considers expanding its risk management program.

Jaselskis and Perez (2019) study

For most of the DOTs reviewed in the synthesis study by Jaselskis and Perez (2019), the level of risk analysis depends primarily on project size and complexity. A common DOT practice is to combine the risk management process with cost estimating and scheduling. For example, TxDOT's approach emphasizes risk-based estimates. WSDOT considers both cost and schedule risk-based estimates where a range of possible values is provided along with corresponding probability distributions. During the planning phase, project managers establish a level of risk assessment based on requirements found in publications such as guidelines, policies, and handbooks. In order to comply with these requirements and as support for the management team, several DOTs have developed series of informational resources that describe methodologies, procedures, and tools that are needed for the implementation of an efficient and standardized risk management process. Methods for sharing information with users range from written resources to webinars and courses. A risk management plan and risk register are the primary sources of information that DOTs use to implement their risk management process.

Several state DOTs recognize the importance of implementing a risk management program for their projects. WSDOT, CALTRANS, NYSDOT, and TxDOT appear to have strong and healthy programs. The approaches taken by CALTRANS, NJDOT, VDOT, and MnDOT consider risk management as a component of the project management framework in which activities are performed throughout the project's life-cycle, without emphasizing a specific context such as cost estimation. The approaches of WSDOT and NDOT are similar to those of the other DOTs reviewed in the Jaselskis and Perez (2019) study, but with greater emphasis on applying procedures for risk-based cost estimation. TxDOT's approach is focused primarily on risk-based cost estimating during the project development phase.

NCHRP Report 658 (Anderson et al. 2006)

The National Cooperative Highway Research Program (NCHRP) Report 658 provides suggestions about ways that agencies can implement risk management processes at the project level. These processes should be considered as components of project management and applied integrally throughout the organization. A 'champion' should be identified who is responsible for tracking the implementation of the risk strategy. The champion should be within the agency's upper-level management hierarchy. At the lower management level, a diverse committee should be formed to develop policies and training materials, support task applications for projects, and communicate risk-related information to users. At the beginning of the implementation process, the inclusion of an external risk management expert from outside the agency should be considered. NCHRP Report 658 also suggests that the risk management team should start with the assessment of actual agency practices. This task must include not only the review of steps or requirements that the agency is using but also the level of knowledge of the personnel within the department. Agency personnel are required to be trained to serve as support for implementing policies. Because risk management is integrated with other management processes, training materials can be included in courses that are already in place, such as cost estimating or cost management courses.

Practices of other state transportation agencies
Many of the risk lists and software, with some modification, which are used by other state DOTs can be adopted for practice by the NCDOT. The literature provides information about ways that estimation components are defined and used by other state transportation agencies.

Exhibit 4 shows the main elements of an estimate: the base estimate (which includes identified items as well as minor allowance items), contingency, management reserve, and inflation. This exhibit is a slightly modified version of the graph used by the CTDOT (Tellier 2019). Descriptions for the base estimate, contingency, management reserve, and inflation are given in the following text.

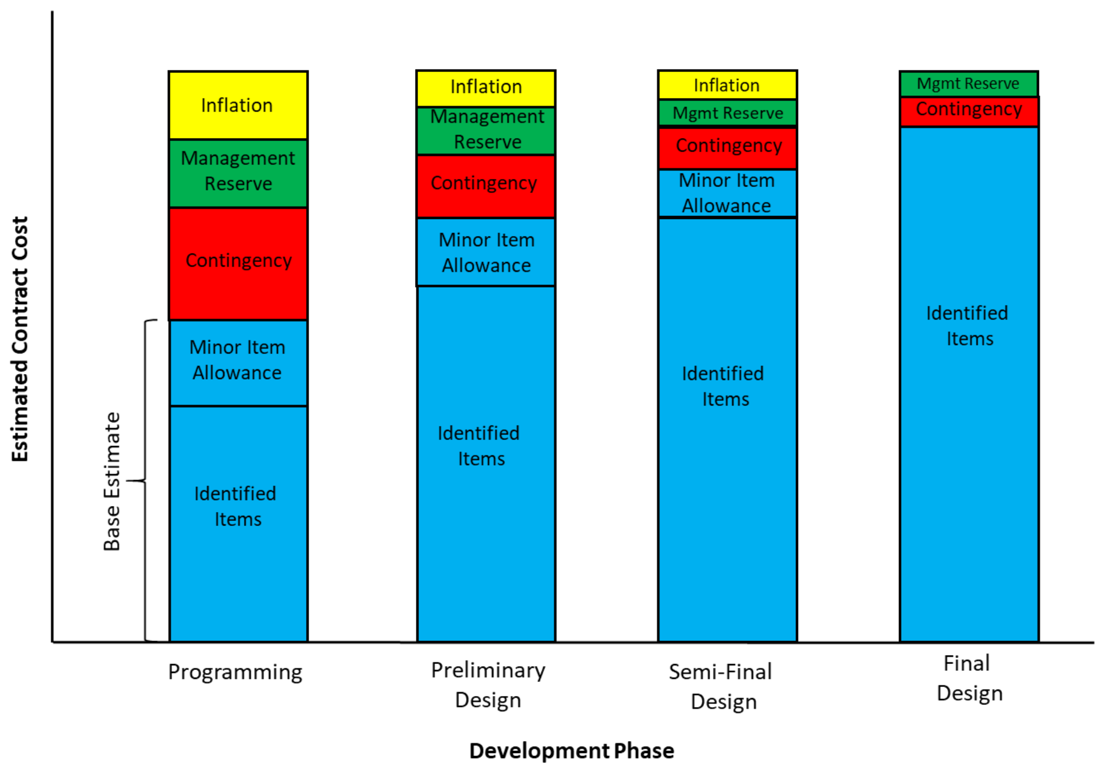


Exhibit 4. Estimated Contract Cost Compared to Development Phase for Connecticut DOT Projects (modified from Tellier 2019)

Base estimate: The Association for the Advancement of Cost Engineering (AACE) (2020) states:

> *The base cost and duration estimate values will reflect aggressive but reasonably achievable current pricing and performance. 'Aggressive but reasonably achievable' means that the assumed performance will reflect the first quartile level (i.e., P25) of*

historical performance or equivalent for similar strategies and scope excluding the impact of identifiable changes and risks.

Escalation, such as inflation, is commonly applied (i.e., added to each budget line item as appropriate) as an allowance in estimates for projects with shorter durations and is identified separately for projects with a longer duration. Allowances are included as part of the base estimate to "cover the cost of known but undefined requirements for an individual activity, work item, account or sub-account" (AACE 2007). The base estimate excludes contingency and management reserves.

Contingency: Contingency is "an amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs" (AACE 2007). The definition of 'contingency' and the use of contingency allowances vary widely in DOTs across the United States. Some agencies limit the use of contingency costs for unpredictable, unforeseeable problems during construction or to cover the cost of inflation in the price of materials on large projects that take years to complete. Others include a high contingency factor in the PS&E package to account for a change in scope (Paulsen et al. 2008). Some of the items, conditions, or events for which the state, occurrence, and/or effect are uncertain include, but are not limited to, planning and estimating errors and omissions, minor price fluctuations (other than general escalation), design developments and changes within the scope, and variations in market and environmental conditions (AACE 2007). Contingency generally is included in most estimates and is expected to be expended (AACE 2007). However, note that the Project Management Institute uses the term 'contingency reserve', which may imply that the amount is not expected to be spent (Hollmann 2016). Contingency generally excludes major scope changes, escalation and currency effects, extraordinary events, and management reserves.

Management reserve: According to the AACE (2007), management reserve is

> *. . . .an amount added to an estimate to allow for discretionary management purposes outside the defined scope of the project, or otherwise estimated. May include amounts that are within the defined scope, but for which management does not want to fund as contingency or that cannot be effectively managed using contingency. Synonyms include: Reserve and Reserve Allowance.*

The AACE (2007) also states:

> *In earned value management according to ANSI EIA 748 standard, management reserve is an amount held outside the performance measurement baseline to handle unknown contingency at the total program level. Management reserve has no scope, is not identified to specific risks, and is not time-phased. It is typically not estimated or negotiated and is created in the budget development process.*

According to Hollmann (2016), the three main reasons for management reserve are:

- To allow for optional changes to the project scope via 'management choice'.
- To cover extraordinarily low probability/high impact risks that are beyond contingency.
- Lack of trust whereby management does not trust the project director/manager to manage risks effectively.

Exhibit 5 shows the risk categories for a project in terms of known versus unknown contingencies. For the most part, the base estimate is known, except for some uncertainty with specified allowances. A contingency allowance is for known-unknown conditions that are project-specific or systemic. For example, at the project level, some parcels of land may require condemnation, but the actual impact is unknown at the time of the estimate. Systemic issues might arise due to biases in the estimate process that result in overly optimistic or pessimistic estimates for certain project types. Management reserve is for taking into account unknown-unknown circumstances as described by Hollmann (2016).

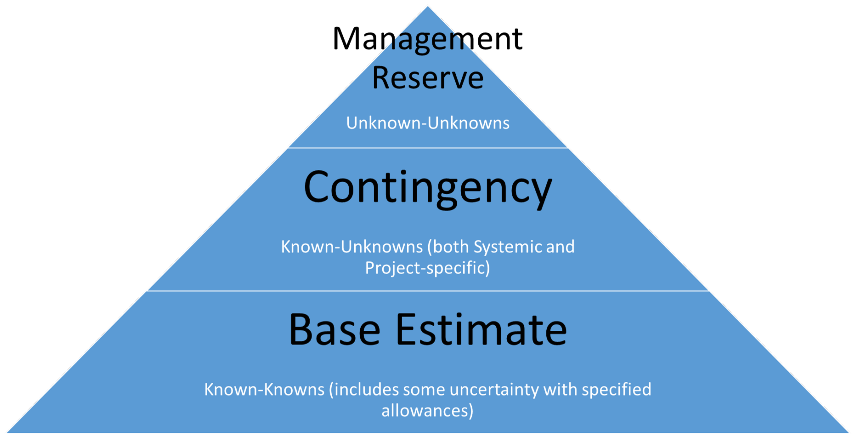


Exhibit 5. Project Risk Categories and Type of Contingency Applied

Inflation: Inflation is an important consideration when developing a project cost estimate. According to Paulsen et al. (2008), cost overruns occur in part due to "failure to account for inflation." According to a 2001 VDOT study, "Most state DOTs do not attempt to account for inflation in their planning-stage project cost estimates but simply maintain estimates in current dollars and update them annually or on an as-needed basis" (Turochy et al. 2001). Inflation is defined by several state DOTs in the following entries; some entries include the DOT's practice to address inflation in their cost estimates.

- CTDOT: "Inflation affects various project cost categories (e.g., rights-of-way, construction) differently since they are incurred at different points in time and have unique cost trends." Exhibit 6 shows the components of CTDOT's estimated contract cost, including the base estimate, contingency, and inflation (Tellier 2019).

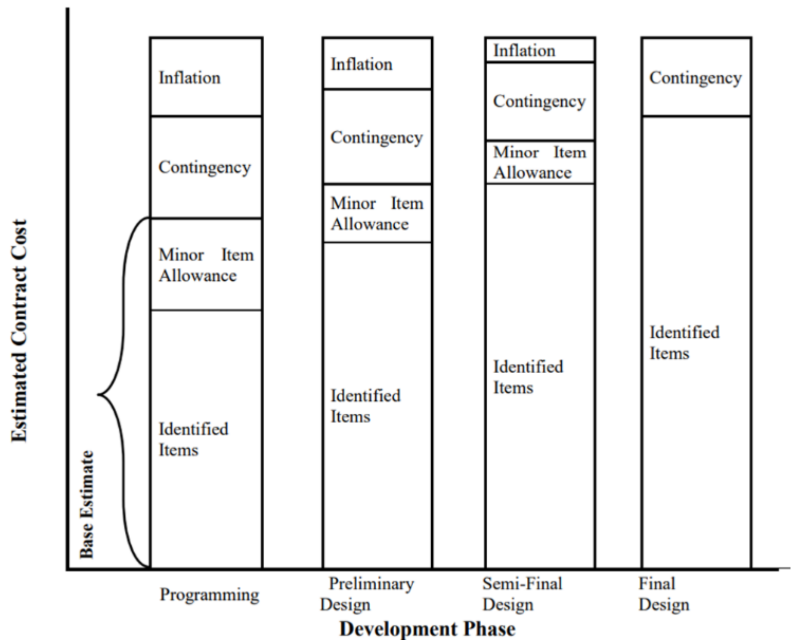


Exhibit 6. Connecticut DOT Estimated Contract Cost Compared to Development Phase (Tellier 2019)

- FDOT: ". . . the proportionate rate of change in the general price level, as opposed to the proportionate increase in a specific price. General inflation erodes consumer purchasing power. Inflation is usually estimated by a broad-based price index, such as the implicit deflator for the Gross Domestic Product or the Consumer Price Index" (FDOT 2020).
- GDOT: "The Office of Financial Management shall be responsible for applying inflation factors to estimates based on the programmed year and current inflation index" (GDOT 2020).
- Idaho DOT (ITD): "The estimate must always be adjusted for inflation by considering the interval of time from when the estimate was performed to the project's construction year. This will allow the estimator to express the project cost estimate in year-of-construction dollars. On average, the general inflation factor to be used is 2% to 3%. It can be assumed that inflation can be applied uniformly among all project bid items." "Rates of inflation are calculated using the current Consumer Price Index published monthly by the Bureau of Labor Statistics as follows: https://www.usinflationcalculator.com/inflation/historical-inflation-rates/" (ITD 2020)**.**
- Michigan DOT: recommends using Federal Highway Administration (FHWA) guidance of 4% annually (Liu et al. 2020).
- MnDOT: "…uses its forecasted state-specific construction cost index in estimating inflation, which shows how closely MnDOT is tracking highway construction inflation relative to its peer states and the nation" (MnDOT 2018).
- NJDOT: "All NJDOT projects are to include inflation when providing future year construction cost estimates. The inflation factor to be used is 3% (simple, not compound) and the inflation adjustment is based on the number of years between the year of estimate and year of project letting date" (NJDOT 2019).

- Ohio DOT: "…generates inflation forecasts depending on bid price trends and nationwide economic trends" (Ohio DOT 2021). Exhibit 7 shows the Ohio DOT's five-year construction cost inflation forecast.

	CY2021	CY2022	CY2023	CY2024	CY2025
High	4.0	6.2	6.1	5.0	6.0
Most Likely	2.0	4.0	3.0	2.1	2.5
Low	-1.0	1.4	2.2	0.0	0.4

Exhibit 7. January 2021-2025: Five-Year Construction Cost Inflation Index (Ohio DOT 2021)

- Oregon DOT: Inflation is part of the project's contingencies. According to Oregon DOT's Project Controls Office Estimating Manual, project contingencies include design progression allowances, inflation, legislative changes, and risk-based contingencies (Oregon DOT 2020).
- PennDOT: "The effects of inflation will add to the cost of a project, independently from contingency costs and cost drivers. The Project Manager and the District Planning and Programming Manager should communicate the inflation factor applied to an estimate. A 3% inflation factor, compounded annually, can be added to the Project Phase estimate in the MPMS system. The MPMS system calculates the inflation factor to the year of expenditure (letting), not the mid-point of construction" (PennDOT 2017).
- SCDOT: "SCDOT complies with the federal year of expenditure requirements for project estimates by including contingency costs that account for inflationary changes, as well as completing routine review and updates of anticipated costs" (SCDOT 2017).
- UDOT: UDOT (2020) provided a construction cost outlook and recommended inflation projections as of December 2020, as shown in Exhibit 8.

	FY2021	FY2022	FY2023	FY2024	FY2025
High	4.5%	4.7%	5.5%	6.5%	7.5%
Recommended	3.7%	3.8%	4.0%	4.5%	5.0%
Low	1.2%	1.5%	1.8%	2.3%	2.8%

Exhibit 8. Executive Summary: Construction Item Inflation (FY = Fiscal Year, July 1 to June 30) (UDOT 2020)

- VDOT: ". . .an increase of expenditure levels resulting from a considerable and prolonged rise in prices and other costs through time without changes in project scope…. inflation will be added to the estimate based on the year of advertisement" (Turochy et al. 2001).
- WisDOT: ". . .adjustment to project estimate based on escalation of bid item unit prices specific to a project, reflecting trends in fuel prices, material costs, contractor competition, and regional economic factors" (WisDOT 2021).

State Transportation Agencies' Estimating Practices

This section describes state DOTs' estimating practices and is based on a broad survey conducted by the NCSU research team that was designed to learn more about contingency, reserve, and general estimating practices for the three main project components (construction, ROW, and utility relocation). The NCSU research team created three separate surveys for each project component of interest; see Appendices A.1, A.2, and A.3, respectively. A survey related to inflation and how it is addressed in the STIP process was added to the study outside this broader survey on estimating.

Construction Contingency, Reserve, and Estimating Practices

Thirteen responses were obtained from cost estimation subject-matter experts who represented state DOTs that covered most regions (East, West, South, Southwest, and Midwest) in the United States. These experts had an average of 18 years of experience in their respective organizations and 14 years of experience estimating projects. They reported their respective DOT's construction contingency, management reserve, and other estimating practices.

Construction Contingency Allowance

Nearly two-thirds of the thirteen DOTs add a contingency allowance to their base construction estimates, mostly for feasibility and intermediate estimates. Fewer (25%) include contingency in their final estimate. Of those respondents who include contingency in their estimates, 50% use one contingency factor for the entire estimate, 13% apply different contingency factors for each main component, and 38% use a varied approach described as follows:

- Apply contingency factors for each main category in small and medium-sized projects and probabilistic risk-based cost estimating for larger, riskier projects.
- Are in the process of transitioning from the use of one overall contingency factor to discipline-specific contingencies.
- Use Monte Carlo simulations (P70) to establish contingency values for major estimate items that comprise more than 1% of the total construction cost.

Of the thirteen DOT respondents, 38% determine contingency using a risk-based approach by identifying project-specific risks, assigning probabilities and impacts to each risk, and multiplying the probability by the cost impact, and 25% of the respondents use a standard contingency that depends on the level of scope definition. A smaller percentage (12%) uses risk modeling, such as Monte Carlo simulations, to determine contingency factors. In addition, 25% of the respondents reported other approaches that are scalable between deterministic risk for less risky 'low-dollar' projects and risk modeling (Monte Carlo simulation) for 'high-dollar' and higher risk projects.

When asked about ways that contingency is linked to their DOT risk management program, 55% of the respondents reported that their DOT does not specifically link contingency to their risk management program. For the DOTs that do, contingencies are defined primarily by identified risks for larger, high-profile projects. Some DOTs are working on a process to link risk to contingency on most of their projects. The responses were not consistent regarding the frequency of the review process for contingency allowances. Some DOTs perform this task annually as part of the STIP development process, but some respondents were unsure of their organization's contingency review and update policy.

Construction Management Reserve Allowance

Nearly two-thirds of the thirteen state DOTs who responded to the construction-related survey do not include reserve funds in their project estimates. Comments from some respondents whose DOTs do include reserve funds are as follows:

- 3.5% of every project is in reserve.
- Project managers include all reserves and contingency in their estimates and use historical data to determine these values.
- Reserve is used for some projects with FHWA oversight for construction overruns. A number is identified during the cost estimate review and then included in the total cost of the project.

Sources of Construction Cost Estimation Data

In order to develop construction cost estimates, most of the thirteen DOT respondents review their previous internal bid history. Some rely on bid-based estimation data from AASHTOWare Project Preconstruction and Data Analytics and the WebTransport Reports databases. In addition, design engineers occasionally obtain information from suppliers and industry to determine costs for unique items without historical information. Most respondents condition their cost data for project location (85%), timeframe (54%), and project size (77%), reflecting economies of scale for larger projects with greater quantities.

Construction Cost Data Update Frequency

The frequency of updating historical construction costs varies widely among these thirteen DOTs, with many departments reporting monthly as bids are received, or quarterly. A limited number of respondents reported annual updates. Note that the updating of historical construction costs may be independent from applying them as a way to estimate future costs and contingencies. Regardless of the frequency of historical construction cost updates, cost contingency policies typically are only reviewed annually.

Construction Cost Data Management

Respondents across the thirteen state DOTs reported that a group manages their construction cost data. Nearly all thirteen DOTs reported separate data managers, including information technology personnel, the State Office Engineer, the Project Controls Office, and others. The different organizational structures of the different agencies may contribute to the variety of data managers that house these data. Data storage systems typically utilize Microsoft products (such as Excel and Access) while others deploy third-party software, such as AASHTOWare that includes data storage.

Construction Estimate Quality Control Practices

Most of the thirteen DOTs have a formal review process for estimating construction costs, at least for high-dollar or high-risk projects. Roughly half of the respondents reported that their DOTs at least compare planned versus actual project costs for construction at the conclusion of projects. However, applying lessons learned to future estimating policies is less common.

Strengths and Weaknesses of Construction Estimating Approaches

When respondents were asked about the strengths and weaknesses of their current estimating processes, several trends emerged related to staffing constraints, poor staff retention, and minimal training for new staff, which consistently limited the functionality of the estimation professionals surveyed. Many areas for improvement were identified, the most common of which is accounting for inflation, which is inadequately addressed by most DOTs' current estimating policies.

Right-of-Way Contingency, Reserve, and Estimating Practices

Thirteen responses were obtained from ROW cost estimation subject-matter experts who represented state DOTs that cover most regions (East, West, South, Southwest, and Midwest) in the United States. These experts had approximately 23 years of experience in their respective organizations and 16 years of experience estimating projects.

Right-of-Way Contingency Allowance

Of the thirteen respondents, 71% add contingency to their base ROW costs, with most DOTs including contingency in all of their estimates (feasibility, intermediate, and final). ROW contingency allowances vary depending on the nature of the project and its location, but generally cover changes in the project scope, eminent domain proceedings, and final settlements. Projects that impact commercial corridors generally have higher ROW contingency allowances compared to projects located in rural areas. One DOT uses contingency allowances for time, counter-offers, condemnations, appraisal costs, etc. One DOT applies a condemnation percentage to the total land, damages, and easement costs to account for typical negotiated settlements and litigation. It then adds a contingency allowance to account for unknowns such as potential hazardous material, or a well/drain-field that is not reflected properly in plans, or when one or two extreme condemnation instances occur. For ROW acquisition, the risk management aspect is based on the likelihood that the agency will pursue eminent domain.

ROW contingency allowances typically are based on a standard value that depends on the specifics of the project. However, one respondent's DOT uses a standard contingency factor that is not dependent on project-specific factors. Some DOTs also base their contingency levels on project-specific risks by assigning cost impacts and probabilities of occurrence using both deterministic and probabilistic risk-based approaches. One respondent stated that, if the scope of work is simply to add better shoulders and the risk of change is limited, then the DOT will include a lower contingency allowance; but, if the unknown impacts are numerous, then the DOT will add a higher contingency allowance. The same respondent also noted that, at the early prescoping/scoping phases, the DOT may apply a higher contingency allowance but reduce it during the life-cycle of the project. By the time the DOT is at the ROW notice-to-proceed (NTP) stage, it may still apply a contingency allowance, but typically the allowance is much lower than in the earlier phases.

Reponses regarding the frequency of ROW contingency reviews and updates varied, but the following responses were typical.

- Project-by-project. Standard contingency percentages are assessed for their suitability for each project.
- Quarterly, during project cash flow meetings.
- Annually.
- Almost never.

Right-of-Way Management Reserve Allowance

Including management reserve funds for ROW is not common. Only one respondent's organization adds 17% to 20% reserve allowance (after contingency is added to the base ROW estimate).

Sources of Right-of-Way Cost Estimating Data

Generally, the sources of ROW cost estimation data include any and all tools and data that are available from local governments, market participants, the U.S. Geological Survey, the U.S. Department of Environmental Protection, and water management districts, which together maintain information related to parcel boundaries, future land use/zoning, roads, drainage systems, subdivision plats, municipal boundaries, urban area boundaries, state lands, tribal lands, hazardous waste sites, underground storage tanks, landfills, petroleum depots, protected/threatened endangered species, national marine fisheries, soils, drinking water wells, land cover, wetlands, aquatic preserves/sanctuaries, conservation and recreation lands, drainage areas, groundwater elevations, flood prone areas, etc. The data also include historical information regarding actual costs for property acquisitions, which may be derived from analyzing sales data or evaluating local master plans, zoning codes, and/or land development plans and may include multiple listing service (MLS) data, appraisers' and tax assessor's records, Register of Deeds records, landowner information, and web-based services with county assessor data as well as current sales data from court-house retrieval and eminent domain coordinators. Other insights regarding sources of ROW cost estimation data include the following.

- The base estimate includes an administrative cost that covers the title report, appraisal, negotiation, and closing on a per parcel basis.
- ROW cost estimators generally perform estimates starting from the preliminary engineering phase through the post ROW phase.
- Excel spreadsheets often are used to prepare estimates.
- ROW costs typically are conditioned for the timeframe, location, and size of the project.
- A reliable cost estimate involves a quasi-appraisal of every single property impacted by the proposed project.
- ROW estimates typically are two-fold: one at the project's conceptual stage and the other after the ROW limits have been set.

Frequency of Right-of-Way Cost Data Updates

For some of the thirteen DOTs, historical costs are not updated at all or are updated infrequently (every five years when the ROW manual is updated). For many of these DOTs, historical ROW costs generally are linked to acquisition business processes and hence are updated in real time. ROW costs can be updated at various milestones of a project, e.g., initial prescoping, scoping, field inspection, as well as the ROW NTP and post ROW NTP phases. One respondent reported that their DOT analyzes administrative costs and condemnation risks, such as trials, annually to verify if any tweaking of administrative costs and or trial/litigation costs is needed. Other respondents noted that ROW cost estimates are performed for each project and reflect present-day costs. Estimates are updated at different intervals, such as annually or at other time intervals or when design changes are needed, by request, or through the identification of new information, etc.

Right-of-Way Cost Data Management

Each of the thirteen DOTs has its own method for managing ROW cost data and uses either centralized or decentralized approaches. In some instances, each district, region, or section manages its own ROW costs. One DOT allows its regions to have access to internal software for historical data when determining administrative and eminent domain costs. One DOT has a ROW office that manages all ROW activities for the department. Based on the survey responses, ROW data typically are stored in an office proprietary enterprise system on a secure internal server. Excel spreadsheets are used to calculate individual cost estimates, with approved estimates maintained in project files.

Right-of-Way Estimate Quality Control Practices

Most of the thirteen DOTs (85%) include a review process for ROW estimates, and some processes are more formal than others. Reviews are performed by district ROW administrators and/or internal staff. Most DOTs (67%) do not compare their planned versus actual ROW costs. One respondent stated that such a comparison is not necessary because the DOT's final costs generally are lower than its initial estimate, which includes a 50% condemnation factor. One DOT respondent stated that the DOT has the capability to compare planned and actual costs through its ROW management system but that this exercise is not formally conducted for each project. One respondent stated that the actual versus planned ROW costs are reviewed annually prior to updating all STIP estimates to identify potential adjustments to the ROW cost estimates. Another said that planned versus actual ROW costs are compared when staff is available to do so and that the review process is based on a simple comparison between planned and actual costs. The respondent noted that the planned ROW costs are likely to be lower than the actual costs, and then they "dig deeper" to determine the lessons that may be learned from individual projects.

Strengths and Weaknesses of Right-of-Way Estimating Approaches

The respondents noted that the strengths of their DOT's ROW estimating approach include constantly updating data and capturing the proposed areas of impact. The approved on-call contract appraisers stay current with changing market trends through actual published sales data and current competitive contract bidding. A respondent reported that their DOT gains additional support from designers in providing ROW data sheets as early as possible in order to include the preliminary engineering phases and noted that this method is imperative to their DOT's success. DOT personnel research the sales for each parcel impacted and do not simply use assessments. They field-inspect projects in the preliminary engineering phases and use Google Earth in every project. They also hold project meetings with the engineers to discuss ROW issues and potential solutions for cost savings, for example, impacts to parking/access. Each district has staff assigned to estimating ROW costs. Most of these individuals have an appraisal background and specialize in valuation for condemnation purposes. The respondent noted that their DOT continually seeks ways to improve the quality of estimates, mainly by ensuring that data, maps, and plans are the most current available. The strengths of that DOT are bolstered by its efforts to limit and avoid ROW impacts and to estimate potential ROW costs up front. The STIP estimates are updated annually, which gives the DOT an opportunity to adjust project estimates following the preliminary design stage and usually following the final design stage. The DOT's strengths include accurately estimating a parcel's fair market value and having appraisal review personnel estimate actual ROW (land, improvements, damages, etc.) costs.

Weaknesses include mostly the challenge of capturing unforeseen litigation costs. A respondent stated that eminent domain attorneys, along with some of their appraisers, have become 'creative' in their counter-offers and that litigating these cases has become extremely expensive. Areas for improvement include estimating legal fees, court settlements, and counter-offers, and having plans that do not change (i.e., adding drainage easements and sediment basins, etc.) during the acquisition process. A respondent noted that information provided in a detailed cost estimate also can be used against the DOT during condemnation actions (eminent domain). Other weaknesses include estimating relocation costs with limited information at estimate time and estimating legal costs that are due to unknowns and the current litigious environment. Weaknesses also can relate to valuation, because a myriad of factors can influence the cost of real estate. One DOT respondent stated that, when trying to prepare an accurate cost estimate, their DOT struggles with plans that do not have correct areas shown. In some cases, more time is needed to prepare numerous estimates over a short time. One area for improvement is better documentation of the information that goes into ROW estimates and better training for estimators.

Utility Relocation Contingency, Reserve, and Estimating Practices

Twelve responses were obtained from utilities subject-matter experts who represented state DOTs that covered most regions (East, West, South, Southwest, and Midwest) in the United States. These experts had 21 years of experience in their respective organizations and 15 years of experience estimating projects.

Utility Relocation Contingency Allowance

Only about 38% of the twelve responding DOTs add a contingency allowance to their utility agreement costs, and most of these allowances are for their feasibility study and intermediate estimates, and an even smaller percentage of DOTs add a contingency allowance to their final estimates. Generally, the DOT uses one contingency factor for the entire base utility cost estimate. One respondent's DOT uses different contingency factors for each type of utility (e.g., water, sewer, power, telecom, etc.). One respondent reported that their DOT does not include contingency allowances because many utility companies already add them to their cost estimate. Most respondents whose DOTs include a utility relocation contingency allowance said that they review their contingency values on an as-needed basis or yearly. None of the twelve DOTs link their utility relocation contingency to their risk management programs.

Utility Relocation Management Reserve Allowance

Most of the twelve respondents stated that their DOT does not include management reserve for utility relocation costs. Only one DOT uses 3.5% of the total project cost as reserve.

Sources of Utility Relocation Cost Estimation Data

The sources of utility relocation cost estimation data varied among the twelve respondents. For feasibility study estimates, DOTs generally obtain utility relocation cost data from historical project data that include previous utility agreements and invoices where average values are used at a program level. Estimating utility relocation costs involves direct communication with utility companies and historical data. Utility agreement estimates are provided for projects that are at the ROW stage. Approximately half of the respondents said that they condition their utility relocation cost data to account for location, project size, and timeframe. More than half of the respondents do not use proprietary or commercial software to develop utility relocation estimates. The remaining DOTs use either in-house software or the AASHTOWare Precon or Heavy Bid packages.

Utility Relocation Cost Data Update Frequency

Responses regarding the frequency of updating historical utility relocation costs varied and include 'not at this time', every two to five years, annually, and every bid letting.

Utility Relocation Cost Data Management

Generally, a DOT's utilities office or section is responsible for managing the utility relocation cost data. For one of the twelve DOTs, data are housed within the central office and are used by regional and statewide utility coordinators. Three of the respondents stated that their DOT does not manage utility relocation cost data. One respondent stated that their section obtains estimates from utility companies for any reimbursable work but that they do not have or keep the information in a database form and request estimates for each situation as it arises. DOTs with a utility relocation cost data management system in place typically use software such as Excel, AASHTOWare Data Warehouse, or ProjectWise.

Utility Relocation Estimation Quality Control Practices

All twelve of the respondents reported that their DOT compares the planned versus actual project utility costs, and one mentioned that such a comparison is one of their DOT's metrics. Estimation quality control practices vary depending on the DOT. One DOT performs quality control during invoicing, and most of the utility agreements go through an audit process at the completion of the utility relocation. Utility companies are required to provide a detailed final invoice with supporting information. One DOT respondent said that recent/historical projects are reviewed not at project closeout but annually in an effort to learn and adapt when completing yearly updates to STIP cost estimates (for all eight years in STIP). Another DOT reconciles at the time of billing. Most of the twelve DOTs include some form of review process for utility relocation cost estimates. One respondent stated that the DOT reviews cost estimates only if problems or concerns with the estimate are found. Another DOT reviews cost estimates, but at the time of the survey did not have good numbers to compare costs.

Strengths and Weaknesses of Utility Relocation Estimating Approaches

With regard to strengths, one of the DOTs relies on its experienced utilities managers/coordinators and information supplied by the utility company. Another DOT estimates its utility relocation costs and is trying to work out some planning level per mile (or per 100 feet) for relocating/replacing utilities to use in its planning-level estimates. The idea is that utility relocation costs for planning estimates would then be updated when estimates become available from the utility company. That is, the DOT updates its planning/STIP cost estimates with updated estimates from the utility company as that information becomes available during the design stage, but this information typically is not available until one to two years prior to bid letting. The use of historical cost data is another strength. Most utility companies know their business well and provide adequate cost estimates. All of the actual cost agreements go through an audit process, and the utility companies must prove expenditures for the project once their work is complete.

Areas for improvement include incorporating market price fluctuations that historical data may not capture and a cost estimating program that updates for industry changes. One respondent replied that no statewide database is available for their DOT and that a cost manual-type procedure is needed. One of the twelve DOTs does not produce its own estimates for utility relocation work but relies instead on information supplied by the utility company. This DOT currently does not have sufficient information for estimation purposes in order to start such a process.

Inflation Survey of State Transportation Agencies

The NCSU research team investigated the state-of-practice for applying inflation in STIP processes through a survey of state transportation agencies. Fifteen state transportation agencies (including the NCDOT) responded to the request for information that included two components of interest: available revenue and project cost. In terms of available revenue, six state DOTs assume that revenues will increase, three have mixed revenue assumptions (such as applying a reduction factor as a conservative approach), and the remaining six DOTs do not directly address inflation of revenue in their STIP process. In terms of project costs, 15 state DOTs assume that project costs will increase. The NCDOT handles inflation on the available funding side as opposed to the project cost side. Exhibit 9 provides a summary of the responses. Most state DOTs include inflation of the project cost in the project estimates to the time of bid letting. The NCDOT accounts for inflation in a fairly unique way compared to the other state agencies who responded to the survey; the NCDOT reduces available funding to account for inflation (Michigan and Tennessee also have methods to reduce the projected revenue forecasts). The survey results indicate that inflation needs to be considered carefully in the estimating process.

State	Adjustment in STIP		Application	STIP Length (years)
	Available Revenue	Project Cost		
Arkansas (ARDOT)	⬆	⬆	Revenue: A small increase in revenue is assumed. Cost: Costs are evaluated by project type to develop average costs and contingencies.	4
Connecticut (CTDOT)	N/A	⬆	Cost: 3.5% inflation.	4
Florida (FDOT)	N/A	⬆	Cost: Range of 2.7% to 3.3% for inflation. Cost estimates are updated at least annually for all right-of-way and construction phases.	4
Georgia (GDOT)	⬆	⬆	Revenue: Federal revenue is inflated 1%, compounded annually. Cost: 2% inflation, compounded annually.	4
Michigan (MDOT)	⬆⬇	⬆	Revenue: Revenues on both the federal and state sides are assumed to continue to grow at the same rates they have grown historically (1.9% for federal and 1.7% for state annual growth rates for the first 10 years of long-range plans; 2.1% for federal and 1.9% for state for remaining years). Cost: 4% inflation.	4
Minnesota (MnDOT)	N/A	⬆	Cost: 4% inflation for FY2022 (4% for FY2023, 5% for FY2024, and 5% for FY2025).	4
North Carolina (NCDOT)	⬇	N/A	Revenue: Reserve funding to account for inflation. 3% for first five years, compounded annually. Held constant for years 6-10.	10
North Dakota (NDDOT)	⬆	⬆	Revenue: Federal revenue is based on federal estimated amounts for each year or a 2% increase over the previous year. Cost: 4% inflation, compounded annually.	4
Pennsylvania (PennDOT)	N/A	⬆	Revenue: Federal funds are based on the federal authorization level and typically are assumed to remain constant for the remainder of the program. State Highway and Bridge Funds reflect estimated revenues to the Motor License Fund. Cost: 3% inflation, compounded annually to the year of expenditure.	12
South Carolina (SCDOT)	⬆	⬆	Revenue: Revenue is increased by 1% inflation, compounded annually. Cost: Cost estimate increases are embedded within contingency factors at the project level (3% for projects less than $20 million and 5% for projects greater than $20 million).	6
South Dakota (SDDOT)	N/A	⬆	Cost: 2% inflation, compounded annually. Cost estimates for all STIP projects are updated each year when building the next STIP.	4
Tennessee (TDOT)	⬆⬇	⬆	Revenue: 5% inflation, compounded annually. Cost: 5% inflation, compounded annually. Cost estimate increases are embedded within contingency factors at the project level (15% for projects less than $15 million and 10% for projects greater than $15 million). To account for unknowns, yearly revenue is reduced by 20%.	3

State	Adjustment in STIP		Application	STIP Length (years)
	Available Revenue	Project Cost		
Virginia (VDOT)	↑ ↓	↑	Revenue: Federal revenue has an assumed growth rate of 1.7%. State law mandates that state revenue estimates are produced by the Virginia Department of Taxation for all of the state revenue sources, which includes all financial and revenue planning for VDOT (the most recent economic outlook and revenue forecast shows some increases and some decreases in revenue sources). Cost: 3.72% inflation, compounded annually.	4
Wisconsin (WisDOT)	↑	↑	Revenue: On an annual basis, an adjustment factor is used for each STIP period in order to account for anticipated changes in revenue (most recent was 1.78%). Cost: Project managers establish the cost estimate ranges for individual projects and update those estimates as needed based on inflationary factors.	4
Wyoming (WYDOT)	N/A	↑	Cost: Typically, approximately 4% inflation.	6

Notes:
Adjust Available Revenue: Changes in available funding/revenue may result from assuming either that purchasing power will decline in future years (which would be the case if there are no changes in the revenue but inflationary factors erode the purchasing power of those funds) or that system user behavior will change (for example, with the gas tax, more or fewer gallons of fuel are consumed, which will lead to increases or decreases in the gas tax, respectively).
Increase Project Cost: Changes in the cost of completing projects are primarily assumed to be associated with inflationary factors (i.e., the same project will cost more in the future than it does today).
Up arrow represents an assumption that the revenue or cost will increase in the future.
Down arrow represents an assumption that the revenue or cost will decrease in the future.
N/A: Not Applicable

Exhibit 9. State Transportation Improvement Program (STIP) Inflation Responses by State Transportation Agency

NCDOT’s Estimating Process for Construction, Right-of-Way, and Utility Relocation

This section provides an empirical assessment of the current estimating process and contingency allowances used for the NCDOT’s project estimates. The research team analyzed actual estimate values and cost data to assess the suitability of the current contingency allowances. The NCDOT provided a summary of its processes and data at the various project stages in an initial project meeting with the Steering Committee. Upon further discussion with Unit personnel, the NCSU research team identified the precise data sources, elements, and resources. Establishing data points across the various time periods (project initiation, intermediate stages, and final cost) to generate accurate contingency allowances was critical. For instance, the Utilities Unit maintains data in a database for project initiation and intermediate project updates, and the Utility Agreement Management System database contains the final cost information. The research team segmented this task into three subtasks, one for each project area (construction, ROW, and utility relocation), to facilitate faster results by project area and decrease the likelihood that the timeline from one area would impact another. Exhibit 10 presents the current method used by the NCDOT to determine the total project cost, beginning with the feasibility (Stage I) estimate through to the final, or actual, cost (Stage IV). The four estimating stages are defined as part of the NCDOT’s integrated project delivery approach as follows:

- Stage I: Project initiation or feasibility study
- Stage II: Alignment defined
- Stage III: ROW established/plan-in-hand
- Stage IV: Plans, specifications, and estimates (PS&E)

ESTIMATE COMPONENTS	PROJECT ESTIMATE				Estimate Comparitor to Bid Amt	Bid Amt	Actual Cost (AC)
	Stage I	Stage II	Stage III	Stage IV			
CONSTRUCTION							
Base Estimate	A						
Roadway	B						
Structures	C						
Construction Utilities	D						
Subtotal	E						
Misc&Mob *							
Roadway	45%	35%	25%	5-15% (10% typ)			
Structures	15%	10%	10%	5-15% (5-10% typ)			
Construction Utilities	15%	10%	10%	5-15% (5-10% typ)			
Subtotal	F						
CONTRACT COST	G = E + F				G	J	K
E&C (15% of Contract Cost) **	H = 0.15*G						L
Total Construction Cost	I = G + H						
UTILITY RELOCATION	**Stage I**	**Stage II**	**Stage III**	**Stage IV**			
Base Utility Relocation Cost	M						
Contingency (25% of Base Cost)	N						
Total Utility Relocation Cost	O=L+M						P
RIGHT-OF-WAY	**Stage I**	**Stage II**	**Stage III**	**Stage IV**			
Base Right-of-Way Cost (Est. Acq.Cost ; Relocation; Asbestos, Abatement, Demo)	Q						
Contingency (0.7 or 0.9* Estimated Acquisition (	R						
Total Right-of-Way Cost	S=Q+R						T
TOTAL PROJECT COST (TPC)	TPC = I+O+S						AC=K+L+P+T

Note: * Miscellaneous ('Misc') represents the contingency for construction; 5% is applied to mobilization ('Mob').
** The 'C' of E&C is the engineering contingency (3% to 5% of contract cost).

Exhibit 10. Current NCDOT Project Cost Management Approach

The three main components of a project are construction, ROW, and utility relocation, and each component has its own contingency allowance, as discussed below.

Construction: Construction estimates include a percentage for Misc & Mob, as shown in Exhibit 10 where mobilization accounts for 5% of the base estimate. Thus, the actual contingency (Misc portion) applied within the contract is shown in Exhibit 11 (e.g., for the Stage I Roadway estimate, the Misc portion is 40% calculated by subtracting 5% from 45%). Note that roadways, structures, and construction utilities have different Misc & Mob factors for each estimation phase (higher for earlier stages and lower for stages closer to the final estimate). The base construction estimate plus Misc & Mob equals the contract cost, which is then compared to the bid amount. The total construction cost includes the addition of engineering and contingency (E&C) to the contract cost. E&C typically amounts to 15% of the contract cost, which breaks down to 10% to 12% for engineering and 3% to 5% for contingency. The NCDOT does not separate contingency from the engineering portion of the E&C calculations in its construction estimates. For purposes of this study, contingency for the construction component is defined as including Misc & Mob as well as the contingency portion of the E&C costs. Mobilization would not normally be included as part of contingency but is included in this study to be more consistent with the NCDOT's current estimating procedures.

Construction Contingency (Misc %)	Stage I	Stage II	Stage III	Stage IV
Roadway	40%	30%	20%	0-10%
Structures	10%	5%	5%	0-10%
Construction Utilities	10%	5%	5%	0-10%

Exhibit 11. Construction Contingency (Miscellaneous Portion Only) by Stage

Right-of-way: The ROW Unit prepares estimates for the Feasibility Unit through the Stage IV PS&E estimates. The base ROW estimate includes expenses such as the land acquisition cost, relocation expenses, and asbestos abatement and demolition (demo) costs. A multiplier of either 1.7 or 1.9 is applied to the estimated acquisition land cost to cover unexpected expenses, such as higher than anticipated acquisition costs at the time of closing and condemnation costs. The ROW Unit selects either 1.7 or 1.9 as the multiplier based on the level of risk for each project and applies it at all four estimation stages. The ROW Unit also assumes that 20% of the project acquisition cost that is spent will be allocated to condemnation costs.

Utility relocation: Utility relocation costs include expenses related to moving affected 'dry' utilities (e.g., power, communication, gas) away from the construction area. Recently, the NCDOT added 25% to utilities agreements to account for other owner-related relocation expenses, such as tree removal and erosion control, which are not presently included in the scope of utilities agreements. 'Wet' utilities, such as water and sewer, are included as part of the construction costs.

Total project cost: The total project cost is the summation of all three aforementioned estimated costs. That is, the final or actual cost is the sum of the final construction costs (including claims and supplementary agreements), ROW costs, and utility relocation costs (cost/payments to utilities) as well as additional owner expenses associated with the utility relocation, e.g., tree removal and erosion control. Some of the actual costs, such as the contract cost, are directly associated with the project; others, such as portions of the engineering costs, may be viewed as indirect costs and thus may not be directly assessed for a specific project. Detailed analysis is reported in the *Total Project Cost Analysis* subsection of this report.

General Project Data Characteristics

The research team collected both estimated, and budgeted actual cost data for a variety of projects, including 434 construction projects, as follows:

- 292 bridge projects
- 35 interstate highway projects (including maintenance and capacity projects)
- 44 rural projects
- 46 urban projects
- 17 highway safety projects

The research team established a sampling plan to collect estimation data for a representative sample of construction projects, as shown in Exhibit 12.

Project Type	Total Available	Suggested Sample Size
Bridges		
< than $1 million	136	40
$1 million - $4.99 million	135	40
> $1 million	21	21
Interstate	35	35
Rural	44	44
Urban	46	40
Highway Safety	17	17
Total	434	237

Exhibit 12. Construction Project Estimation Sampling Plan

As shown in Exhibit 13, which presents available project data, the Construction Estimation Unit provided a significant amount of estimation data for each of the four project stages. For example, the Unit provided 117 Stage I estimates, 127 Stage II estimates, 183 Stage III estimates, and 248 Stage IV estimates. The Utilities and ROW Units provided utility relocation agreements and ROW cost data for 565 and 234 projects, respectively, but estimation data for these two categories were sparse or not available. According to ROW Unit personnel, obtaining robust ROW estimation data for most (if not all) of the completed projects in the sample was impossible; these data include estimates by stage, assumed contingency factors, and dates. Furthermore, actual construction costs were provided but without breakdown by roadway, structures, and construction utilities. For the utility relocation data, the total purchase order (PO) value was assumed to be equivalent to the Stage IV estimate. Prior utility relocation cost estimates could not be obtained.

COST COMPONENT	Stage I Estimate ($)	Stage II Estimate ($)	Stage III Estimate ($)	Stage IV Estimate ($)	Bid Amount ($)	Budget ($)*	Actual Cost ($)**
CONSTRUCTION	117	127	183	248	431	248 (3)	431 ***
Roadway							
Structures							
Construction Utilities							
Misc&Mob							
Engineering & Contingency (E&C)****							No Data
UTILITY RELOCATION	No Data					565	565
RIGHT-OF-WAY	234			No Data		234	234

Note: *Budget: construction (Stage IV contract cost plus contingency); ROW (funded amount): utility relocation (total purchase order value).

** Actual cost: construction: (estimate to date at 100% complete); ROW (expended amount); utility relocation (cost / payments)

*** Not broken down by major category (i.e., roadway, structures, and construction utilities)

**** Actual engineering cost is missing

Exhibit 13. Available Project Data

Total Project Cost Analysis

This analysis aims to assess the proportions of the total project cost. The data used to determine the total project cost are the final construction cost, final ROW cost, and final utility relocation cost. The STIP number was used to match the project components and to identify the project type. For example, the project with the STIP number B-4943 indicates that the project is a bridge-type project, and the project with the STIP number U-5925 indicates that the project is an urban project. In total, 52 projects have final costs for the three components (construction, ROW, and utility relocation). Exhibit 14 shows the distribution of the project types. Note that the majority of the projects included in this analysis were bridges, and the engineering costs (E&C) were excluded from the total project cost. The formula for the total project cost is:

$$\textit{Total Project Cost} = \textit{Final Construction Cost} + \textit{Final ROW Cost} + \textit{Final Utility Cost}$$

Project Types	Number of Projects	Percentage (%)
Bridge	40	76.9
Rural	5	9.6
Highway Safety	4	7.7
Urban	3	5.8
Total	**52**	**100**

Exhibit 14. Project Types Used in Total Project Cost Analysis

After calculating the total project cost, the proportions of the individual components were calculated by dividing the component cost by the total project cost. For example, the proportion for construction was computed using the following formula:

$$Construction\ (\%) = (Final\ Construction\ Cost\ /\ Total\ Project\ Cost) \times 100$$

The proportions of ROW (%) and utility relocation (%) also were calculated using the above formula. Exhibit 15 shows the box plots for the proportions of the three components. Clearly, the construction portion comprises most of the total project cost. On average, the construction portion is nearly 85% of the total project cost followed by ROW and utility relocation, which are nearly 11% and 5%, respectively, of the total project cost. Exhibit 16 reports the summary statistics obtained from the analysis.

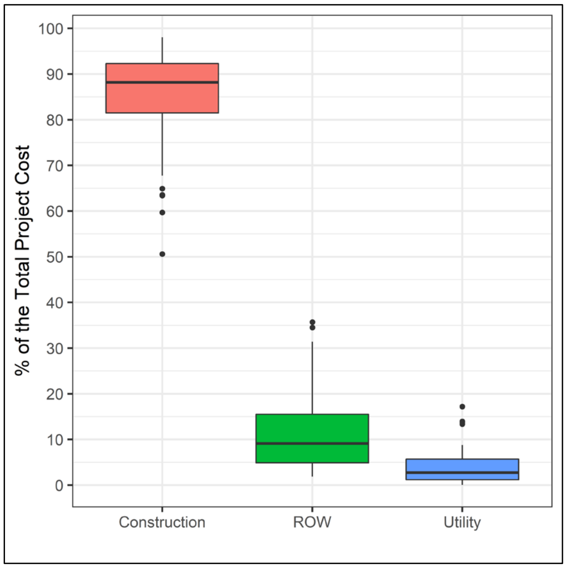


Exhibit 15. Box Plots for Proportions of Construction, Right-of-Way, and Utility Relocation Costs Derived from Total Project Cost

Component	N	Mean	Median	Standard Deviation	Q25	Q75	Standard Error
Construction	52	84.7%	88.2%	11.3%	81.5%	92.3%	1.6%
ROW	52	11.3%	9.1%	8.6%	4.9%	15.5%	1.2%
Utility Relocation	52	4.0%	2.8%	3.9%	1.2%	5.7%	0.5%

Exhibit 16. Summary Statistics for Proportions of Construction, Right-of-Way, and Utility Relocation of Total Project Cost

Analysis of variance (ANOVA) was conducted to assess whether the proportions of the three components had any statistically significant differences between them. The ANOVA results showed a statistically significant difference between at least two project components (F-value = 1427.27, p-value = < 0.001). When the p-value was less than 0.001, Tukey multiple comparison tests were conducted pairwise (e.g., between construction and ROW). Clearly, construction was found to be statistically significantly different from the two other components (ROW and utility relocation). The Tukey multiple comparison results also revealed a statistically significant difference between ROW and utility relocation and showed that the amount allocated for ROW will be statistically greater than that for utility relocation. The findings from this analysis can be used to budget and estimate the three major components of a transportation project.

The assessment of the current NCDOT contingency allowances is discussed in the following sections for each of the three project components in terms of project data.

Construction Project Data

This section provides detailed descriptions of the construction data that include percentage breakdowns for roadways, structures, and utility relocations, as shown in Exhibit 17, time to letting date for each estimation stage (Exhibit 18), and change in project length from one estimation stage to the next (Exhibit 19). Stage I estimates are subject to inflation bias and scope changes that affect the final estimate. Presently, no inflation allowance is added to the estimates to bring costs to a common date, such as the bid letting date, because inflation is considered on a program-level basis. On average, approximately four years transpires between the Stage I estimate to the bid letting date. If a 3% inflation factor is assumed, then the Stage I estimate would increase by approximately 13% (1+0.03)^4 to move it to the time of bid letting. Not surprisingly, the project scope undergoes substantial changes from Stage I to Stage IV (particularly for bridge projects) as measured by the length of the project in miles (Exhibit 19).

Project Type	**Roadway**	**Structures**	**Utility Relocation**
Bridge (117)			
< 1$ million (39)	42.5%	56.2%	0.1%
$1 million to $4.99 million (58)	43.8%	52.9%	0.2%
> $5 million (20)	38.4%	60.3%	0.1%
Interstate Capacity (7)	83.1%	15.8%	0.1%
Interstate Maintenance (26)	89.2%	10.8%	0.0%
Urban (40)	72.5%	18.0%	1.0%
Rural (41)	80.4%	15.9%	0.3%
Highway Safety (17)	89.3%	8.8%	0.1%

Exhibit 17. Construction: Percentage Breakdown for Roadway, Structures, and Utility Relocation by Construction Project Type

Time to Letting Date (Years)			
Stage I	**Stage II**	**Stage III**	**Stage IV**
4.0	2.9	1.3	0.1

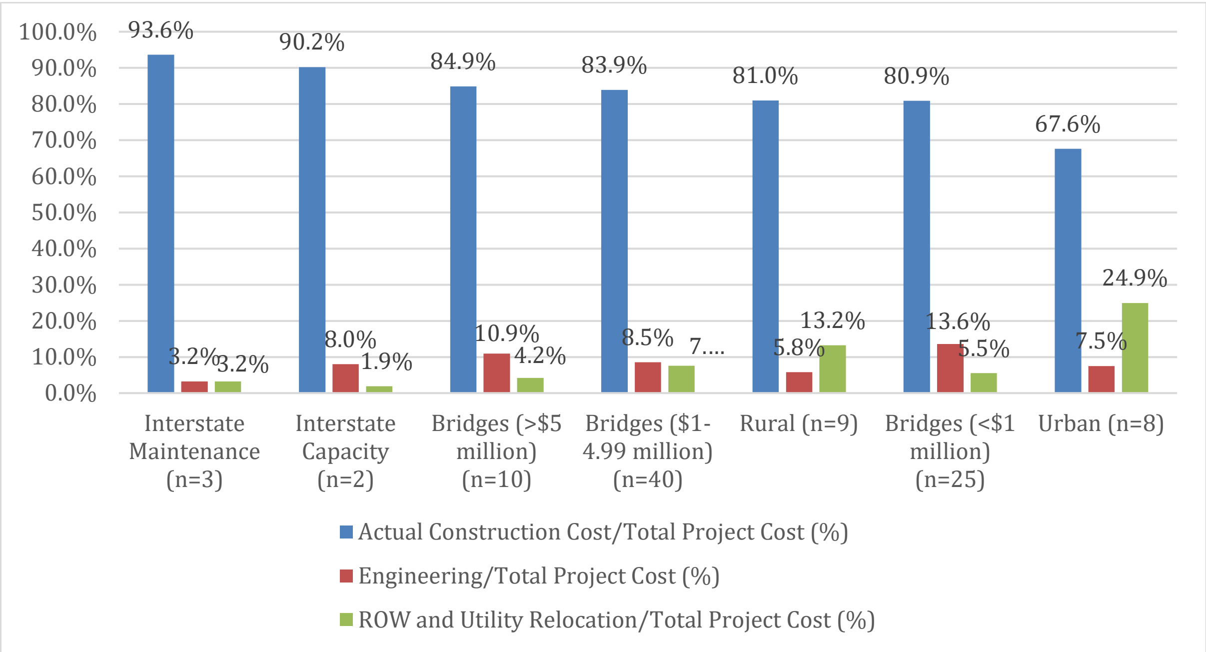
Exhibit 18. Construction: Average Time to Letting Date

Project Type	Change in Project Length (%)			
	Stage I to II	Stage II to III	Stage III to IV	Stage I to IV
Bridge				
< 1$ million	-13.2%	10.5%	23.1%	71.4%
$1 million to $4.99 million	24.2%	6.7%	6.3%	26.1%
> $5 million	49.8%	5.6%	10.4%	42.0%
Interstate	*	28.5%	2.4%	-8.6%
Urban	*	12.2%	-4.9%	12.1%
Rural	13.0%	-5.0%	20.0%	1.7%
Highway Safety	*	*	*	*

*Insufficient data

Exhibit 19. Construction: Change in Construction Project Length by Estimating Stage

Exhibit 20 shows the total construction project cost breakdown by project type. Urban projects have the highest percentage of ROW and utility relocation costs. Interstate maintenance projects have the highest construction cost percentage, which includes roadway, structures, and utility relocations relative to the total project cost.

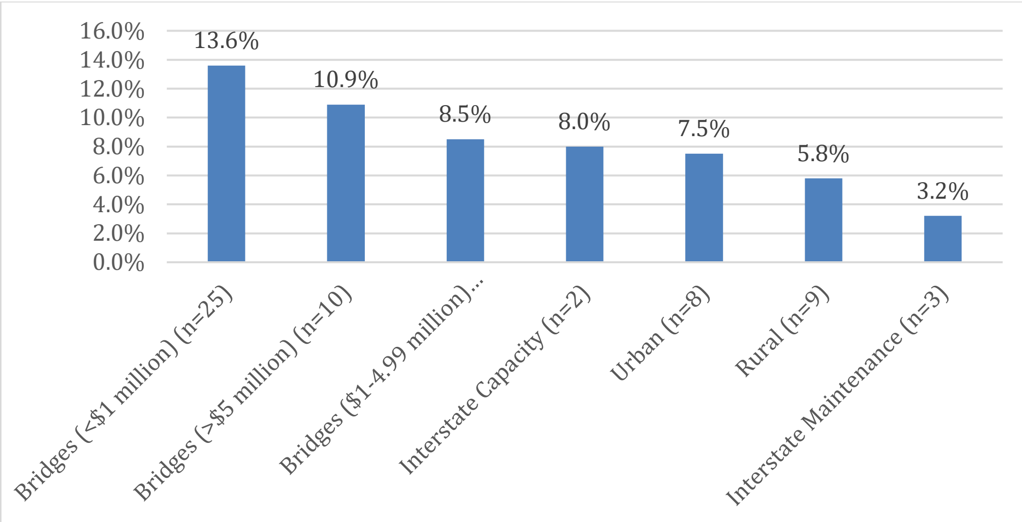


Note: Total project cost = actual construction cost + ROW and utility relocation costs + Stage IV engineering cost estimate.

Exhibit 20. Construction: Total Cost Breakdown by Project Type

Exhibit 21 shows the engineering-to-total project cost ratios/percentages. As the actual engineering costs could not be obtained for this study, the Stage IV estimated value for the E&C cost was used.

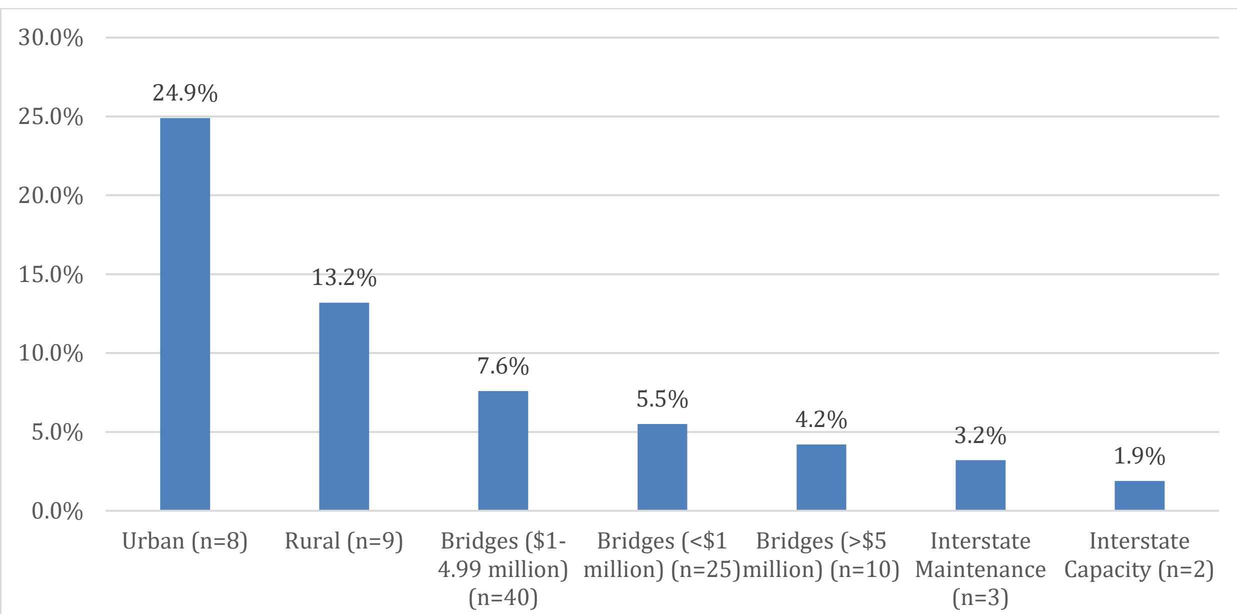
The total project cost equals the actual construction cost plus ROW and utility relocation costs plus the Stage IV engineering cost estimate.



Notes: Engineering cost is based on the Stage IV estimate (E&C).
Total project cost = actual construction cost + ROW and utility relocation costs + Stage IV engineering cost estimate.

Exhibit 21. Construction: Engineering-to-Total Construction Project Cost Ratios (%)

Exhibit 22 shows the ROW and utility relocation costs relative to the total construction project cost. Urban projects have the highest percentage of total cost allocated to ROW and utility relocations compared to interstate capacity projects, which have the lowest percentage.



Note: Total project cost = actual construction cost + ROW and utility relocation costs + Stage IV engineering cost estimate.

Exhibit 22. Construction: Right-of-Way and Utility Relocation-to-Total Construction Project Cost Ratios (%)

Construction Estimation Performance

The Stage IV estimate was compared to the bid amount to assess the estimation performance. On-target estimates were within +/- 10% of the bid amount. Estimates were considered low if they were below 10% of the bid amount and high if they were above 10% of the bid amount. As shown in Exhibit 23, 25% of the construction estimates are considered low, 57% are on target, and 18% are considered high. The highway safety, interstate capacity, interstate maintenance, bridge ($1-$4.99 million), urban, and bridge (>$5 million) projects comprised most of the low estimates. Note that data were limited for interstate capacity (n = 7) and highway safety (n = 7) projects. Exhibit 24 shows projects whose Stage IV estimate is low by about 10% of the bid amount.

Project Type	**Stage IV Estimate Compared to Bid Amount**		
	High (>+10%)	**On Target (-10% to +10%)**	**Low (<-10%)**
Bridge (117)			
<$1 million (39)	41% (16)	51% (20)	8% (3)
$1 million to $4.99 million (58)	16% (9)	60% (35)	24% (14)
>$5 million (20)	20% (4)	65% (13)	15% (3)
Interstate Capacity (7)	29% (2)	43% (3)	29% (2)
Interstate Maintenance (26)	15% (4)	50% (13)	35% (9)
Urban (37)	8% (3)	70% (26)	22% (8)
Rural (41)	15% (6)	71% (29)	15% (6)
Highway Safety (7)	0% (0)	43% (3)	57% (4)
All Project Average (235)	18% (44)	57% (142)	25% (49)

Exhibit 23. Construction: Stage IV Construction Estimation Performance Compared to Bid Amount

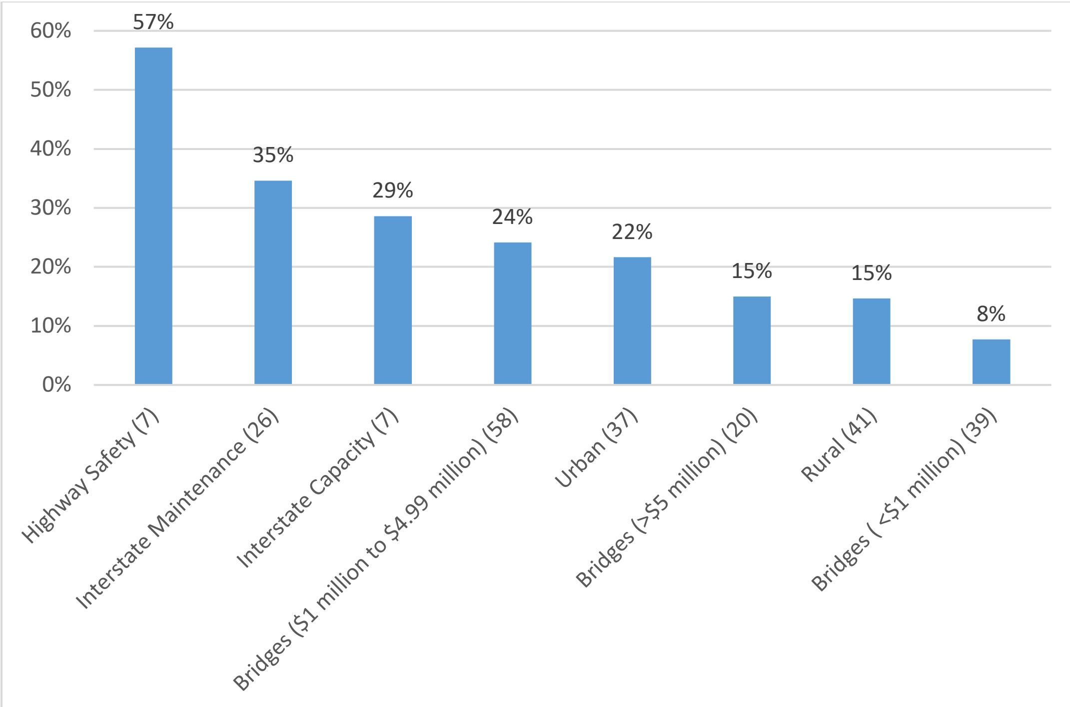


Exhibit 24. Construction: Low Stage IV Construction Estimate Compared to Bid Amount (<-10%)

Exhibit 25 shows the estimation performance by region and that the Western region of North Carolina has the largest percentage of high Stage IV estimates (Stage IV estimates > 10% of bid amount).

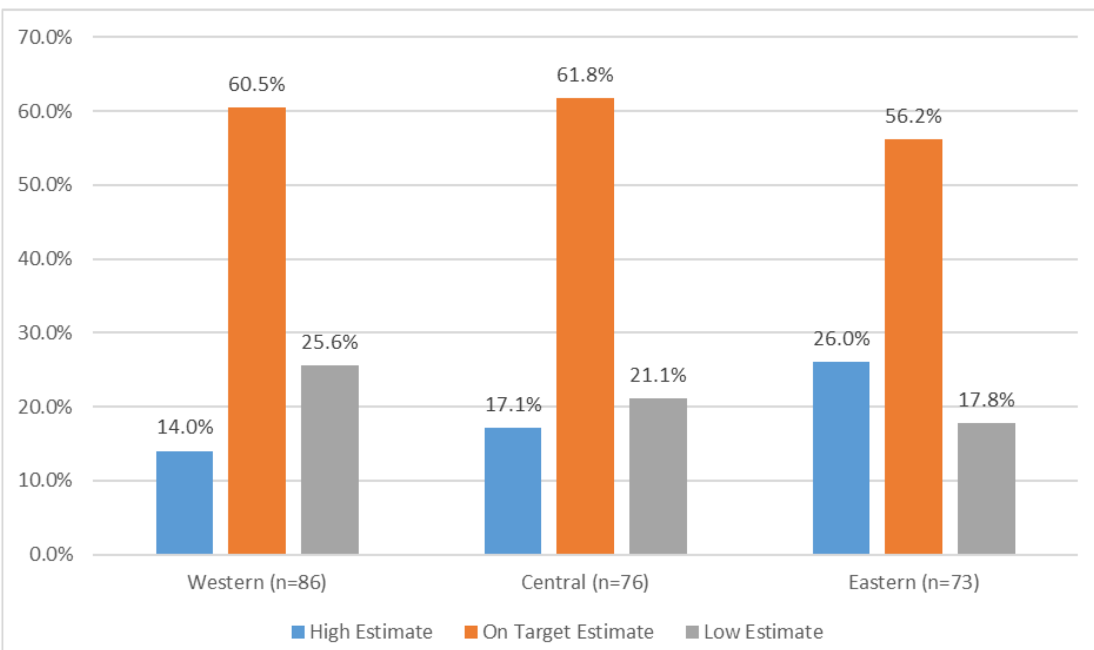


Exhibit 25. Construction: Construction Estimating Performance by Region

Exhibit 26 provides more information about each construction project type, including the percentage of projects in each category and average contract bid amount. Average costs per mile for the Stage IV estimate, bid amount, and actual costs were provided for several project types. Note that the cost per mile varies for each project type. For example, for urban projects with low estimates, the Stage IV estimate is $7,950,824 and the bid amount is $9,468,936, whereas the actual cost per mile is $10,606,664.

Project Type	**Stage IV Estimate Compared to Bid Amount**		
	High (>+10%)	**On Target (-10% to 10%)**	**Low (<-10%)**
Bridge (117)			
< 1$ million (39)			
% of Projects (n)	41% (16)	51% (20)	8% (3)
Avg Contract Bid Amount	$470,958	$530,960	$496,217
Stage IV ($/mile)	$7,064,846	$7,389,858	$6,844,418
Bid Amount ($/mile)	$5,864,788	$7,324,778	$7,752,355
Actual Cost ($/mile)	$5,633,979	$6,879,024	$6,733,026
$1 million to $4.99 million (58)			
% of Projects (n)	16% (9)	60% (35)	24% (14)
Avg Contract Bid Amount	$2,181,583	$2,148,073	$1,800,722
Stage IV ($/mile)	$17,079,542	$11,977,849	$9,071,452
Bid Amount ($/mile)	$14,502,980	$12,168,124	$10,867,518
Actual Cost ($/mile)	$14,207,819	$12,310,561	$10,704,268
> $5 million (20)			
% of Projects (n)	20% (4)	65% (13)	15% (3)
Avg Contract Bid Amount	$21,327,847	$8,361,073	$9,292,095
Stage IV ($/mile)	$35,186,522	$19,957,701	$11,626,917
Bid Amount ($/mile)	$31,211,236	$20,227,767	$13,915,403
Actual Cost ($/mile)	$33,891,176	$20,995,020	$14,436,838
Interstate Capacity (7)	29% (2)	42% (3)	29% (2)
Interstate Maintenance (26)			
% of Projects (n)	15% (4)	50% (13)	35% (9)
Avg Contract Bid Amount	$3,538,339	$19,823,148	$11,611,368
Avg Stage IV Cost Per Mile	$1,639,848	$6,342,968	$4,856,661
Avg Bid Amount Cost Per Mile	$1,381,000	$6,368,392	$5,684,691
Avg Actual Cost Per Mile	$1,644,252	$7,445,261	$6,467,144
Urban (37)			
% of Projects (n)	8% (3)	70% (26)	22% (8)
Avg Contract Bid Amount	$25,336,614	$30,160,007	$7,739,046
Avg Stage IV Cost Per Mile	$12,811,903	$9,837,471	$7,950,824
Avg Bid Amount Cost Per Mile	$11,192,073	$9,935,811	$9,468,936
Avg Actual Cost Per Mile	$12,122,326	$10,556,620	$10,606,664
Rural (41)			
% of Projects (n)	15% (6)	71% (29)	15% (6)
Avg Contract Bid Amount	$18,118,646	$24,522,050	$35,056,866
Avg Stage IV Cost Per Mile	$4,041,021	$8,758,360	$8,257,826
Avg Bid Amount Cost Per Mile	$3,532,534	$8,773,809	$12,865,267
Avg Actual Cost Per Mile	$3,543,023	$9,018,695	$13,505,827
Highway Safety (7)	0% (0)	43% (3)	57% (4)

Exhibit 26. Construction: Detailed Stage IV Construction Estimates Compared to Bid Amount

Construction Contingency Allowance (Misc & Mob)
As previously mentioned, the true construction contingency is the Misc portion of Misc & Mob (refer to Exhibit 27 for Misc & Mob percentages) where mobilization amounts to 5 percent. Because a breakdown of the actual costs for each major component was unavailable, verification of the adequacy of these contingency values was a difficult task. Thus, a weighted contingency factor was determined, as discussed later in the report.

Category	Misc & Mob (% of Base Estimate)			
	Stage I	Stage II	Stage III	Stage IV
Roadway	45%	35%	25%	5%-15% (10% typical)
Structures	15%	10%	10%	5%-15% (5%-10% typical)
Utility	15%	10%	10%	5%-15% (5%-10% typical)

Exhibit 27. Construction: Current Miscellaneous and Mobilization (Misc & Mob) Percentages

Engineering Contingency Allowance
As shown in Exhibit 28, the E&C is calculated by taking 15% of the contract cost, although some projects use 10% for the E&C cost. Engineering includes the administrative costs, construction engineering and inspection costs, etc. At present, the NCDOT does not separate the contingency portion from the engineering portion of the E&C calculation in its estimates. Based on discussions with the construction estimators, contingency is 3% to 5% and engineering costs range from 10% to 12% of the contract cost. E&C estimate values were provided but not the actual engineering costs by project, as some costs are indirect and not charged directly to a particular project. Also, the E&C allowance is not a true 10% or 15% of the contract cost. NCDOT estimators multiply the construction contract cost by the appropriate 10% or 15% and then round, as shown below. They then define the E&C as the difference between the rounded amount and the contract cost. Sometimes the E&C is much higher than the percentage shown.

- < $1,000,000 – round to next $25,000
- $1,000,000 to $5,000,000 – round to next $50,000
- > $5,000,000 – round to next $100,000

Category	Engineering & Contingency (% of Contract Cost)			
	Stage I	Stage II	Stage III	Stage IV
E&C	15%	15%	15%	15%
Engineering	10%-12%	10%-12%	10%-12%	10%-12%
Contingency	3%-5%	3%-5%	3%-5%	3%-5%

Note: Sometimes E&C is 10% of the contract cost.

Exhibit 28. Construction Projects: Engineering and Contingency

Assessment of Current Construction Misc & Mob Percentages

Exhibit 29 shows the contract cost-to-actual cost ratio for each project type and phase. In order to construct this table, projects that were missing the Stage I estimates, bid amounts, or actual costs were removed, which left very few projects in some categories, such as interstate capacity and maintenance. Stage II data were missing for interstate maintenance projects. Each estimate and bid amount were normalized to the actual cost by dividing the estimated value by the actual cost. For most projects (except for bridges < $1 million where the Stage I estimate is higher than the actual cost), the Stage I estimate is lower than the actual cost. Interstate capacity and maintenance projects appear to have the worst estimation performance, with Stage I cost-to-actual cost ratios of 0.56 and 0.51, respectively. Even for the Stage IV estimates, the interstate estimates are low compared to the actual cost. Bid amounts are closer to the actual cost except for interstate maintenance projects where the ratio is 0.74. Exhibit 30, Exhibit 31, and Exhibit 32 present this information (estimation performance) in graphical form. Note that the estimates have not been adjusted to account for inflation. If inflation were added to urban projects at Stage I, for example, then the actual cost-to-estimated Stage I cost ratio would be some value higher than 0.74. Bid amounts are assumed to include the necessary inflation allowance as this allowance is included in the contractor's budget.

Project Type (n)	**Stage I**	**Stage II**	**Stage III**	**Stage IV**	**Bid Amt**	**Actual Cost**
Bridge (<$1 million) (25)	1.11	1.01	1.12	1.16	1.06	1
Bridge (>$5 million) (10)	0.75	0.77	0.84	0.97	0.94	1
Bridge ($1-$4.99 million) (40)	0.73	0.76	0.82	0.96	1.01	1
Urban (8)	0.74	0.92	0.91	0.93	0.98	1
Rural (9)	0.75	0.78	0.82	0.91	0.91	1
Interstate Capacity (2)	0.56	0.51	0.61	0.84	0.99	1
Interstate Maintenance (4)	0.51	Missing	0.72	0.69	0.74	1

Exhibit 29. Construction: Construction Contract Cost-to-Actual Cost Ratio

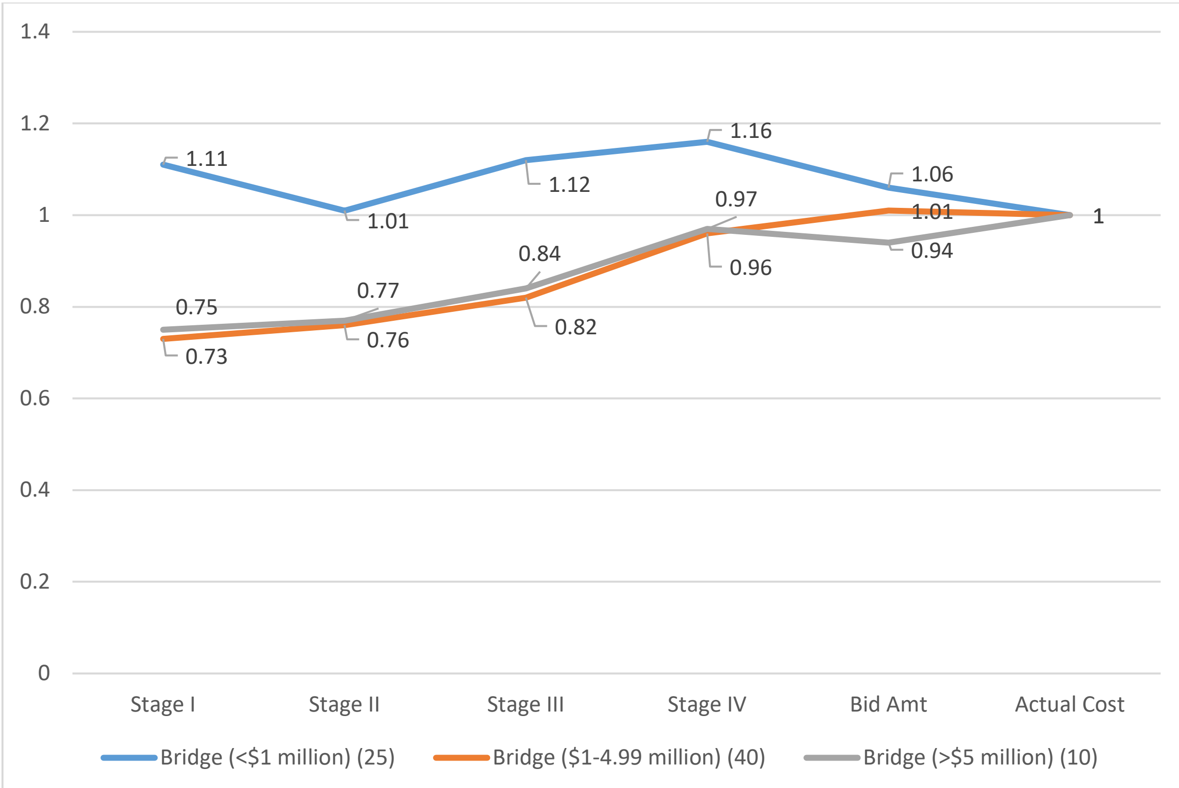


Exhibit 30. Construction: Bridge Estimation Performance (Normalized to Actual Cost)

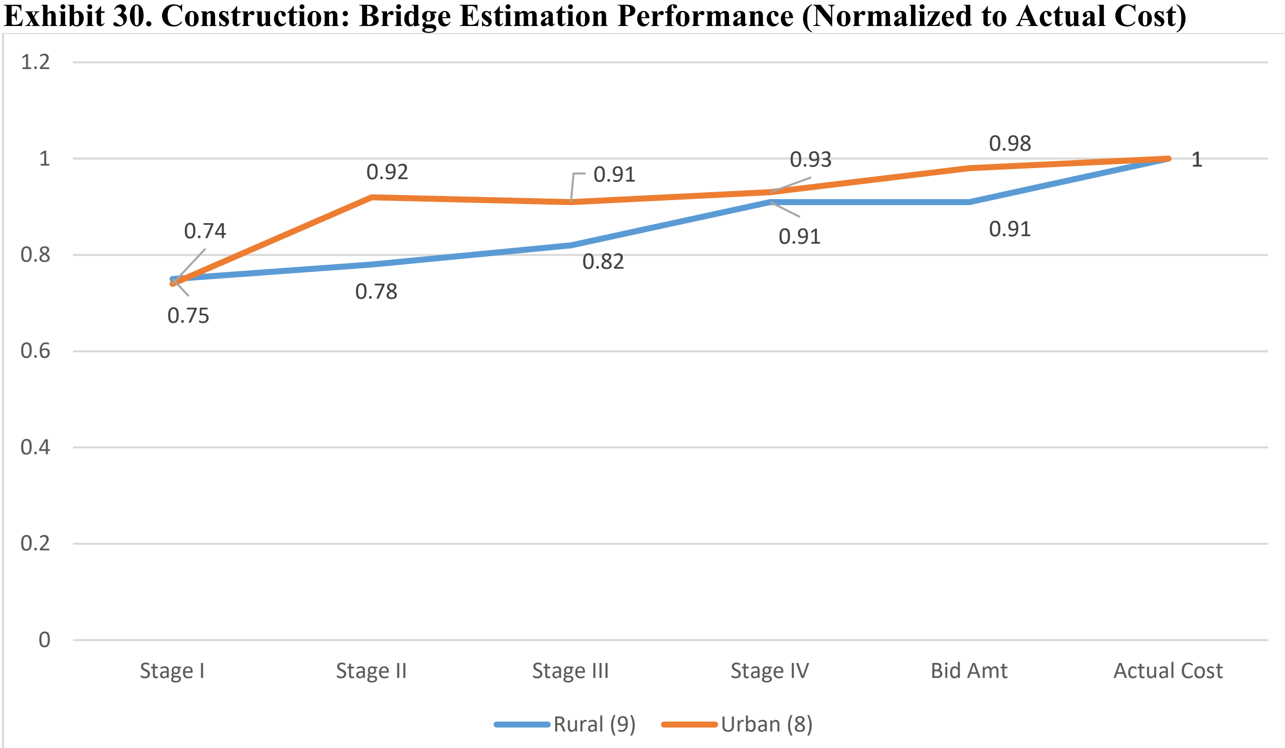


Exhibit 31. Construction: Rural vs Urban Estimation Performance (Normalized to Actual Cost)

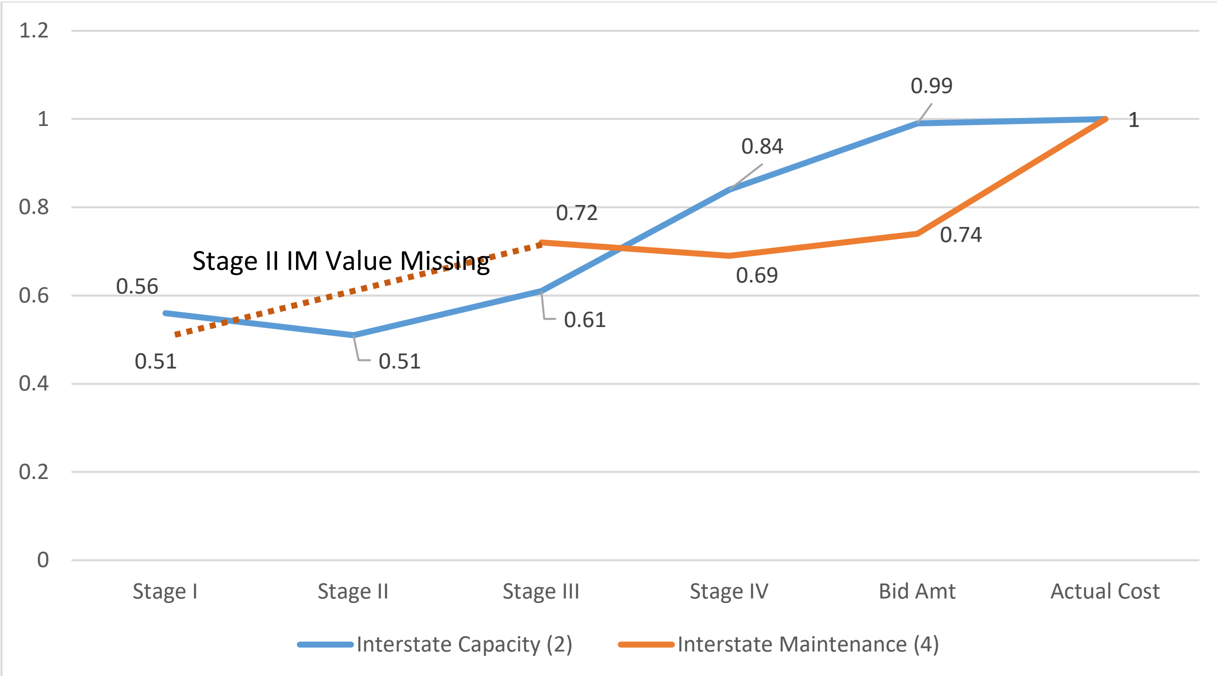


Exhibit 32. Construction: Interstate Project Estimation Performance (Normalized to Actual Cost)

Exhibit 33 shows how the weighted Misc & Mob percentages were calculated using Stage I estimates as an example. First, the percentage contribution of each element in the estimate was determined by calculating the average contribution for each project type. For example, for bridge projects < $1 million, roadways represent 35.7% of the contract cost, structures 64.3%, and utility relocations 0 percent. These percentages were multiplied by the average Misc & Mob percentage for each element and added together to obtain the weighted Misc & Mob percentage. Thus, the weighted Misc & Mob percentage is 26.2% for the smaller bridge projects. The total Misc & Mob would be calculated by multiplying the weighted Misc & Mob percentage by the base roadway, structure, and construction utility relocation estimates. The weighted Misc & Mob percentages were calculated for each estimation stage for each type of project. Exhibit 34 shows the weighted Misc & Mob percentages for the Stage IV estimates and indicates that the weighted Misc & Mob percentages decrease.

Project Type	Stage I (Misc & Mob)							
	Elements				Misc & Mob (%)			
	#	Roadway %	Structures %	Utilities %	Roadway	Structures	Utilities	Weighted
Bridge (<$1 million)	25	35.7%	64.3%	0.0%	46.2%	15.1%	5.0%	26.2%
Bridge ($1-4.99 million)	40	38.8%	60.3%	0.8%	51.4%	15.5%	5.8%	29.3%
Bridge (>$5 million)	10	23.1%	76.0%	0.9%	45.8%	15.0%	9.0%	22.0%
Interstate Capacity	2	97.3%	2.7%	0.0%	45.0%	10.1%	5.0%	44.1%
Interstate Maintenance	3	71.1%	28.9%	0.0%	44.9%	11.7%	5.0%	35.3%
Rural	9	91.9%	6.9%	1.3%	44.0%	10.6%	8.3%	41.2%
Urban	8	74.3%	19.9%	5.8%	48.0%	22.0%	15.1%	40.9%

Exhibit 33. Construction: Calculation of Weighted Misc & Mob Percentages for Stage I Construction Estimates

Project Type	Stage IV (Misc & Mob)							
	Elements				Misc & Mob (%)			
	#	Roadway %	Structures %	Utilities %	Roadway	Structures	Utilities	Weighted
Bridge (<$1 million)	25	42.0%	57.0%	1.0%	11.6%	6.8%	5.0%	8.8%
Bridge ($1-4.99 million)	40	45.2%	51.3%	3.5%	11.4%	7.1%	6.9%	9.0%
Bridge (>$5 million)	10	37.8%	60.6%	1.7%	9.5%	7.5%	6.3%	8.2%
Interstate Capacity	2	88.4%	9.9%	1.7%	12.3%	10.0%	10.0%	12.0%
Interstate Maintenance	3	81.1%	18.9%	0.0%	10.1%	5.0%	5.0%	9.1%
Rural	9	86.4%	10.9%	2.8%	11.7%	5.7%	6.0%	10.9%
Urban	8	72.8%	18.6%	8.6%	12.4%	5.0%	9.2%	10.7%

Exhibit 34. Construction: Calculation of Weighted Misc & Mob Percentages for Stage IV Construction Estimates

To determine the required Misc & Mob percentages in order to predict actual costs, the research team devised another set of calculations, shown in Exhibit 35. A base cost of $100 was assumed for roadways, structures, and utility relocations. In this example, the weighted Misc & Mob percentages were used to determine the contract cost for each project type. For example, for urban projects, the Stage I estimate weighted Misc & Mob percentage is 40.9 percent. Note that the weighted Misc & Mob percentages were determined using both the average and median values of the construction project data. For this example, the average value was used. The Stage I estimate with Misc & Mob is $140.94, which is also the Stage I contract cost. Note that the Stage I cost-to-actual cost ratio is 0.74, which implies a Stage I cost-to-actual cost multiplier of 1.35 (reciprocal of 0.74). In other words, the Stage I estimate should actually be 1.35 times greater in order to predict the actual cost of $190.46. Thus, the actual total Misc & Mob amount should have been $90.46 instead of the estimated $40.90. This cost represents a weighted Misc & Mob percentage of 90.5% instead of the 40.9% that was used for the Stage I estimate. Thus, the current Stage I estimate weighted Misc & Mob percentage would need to be increased by 49.5% in order to predict the actual project cost more accurately. Note that these percentages include inflation, as they reflect the actual project cost. Thus, these proposed Misc & Mob percentages include miscellaneous, mobilization, and inflation.

Project Type	Stage I (Misc & Mob)							
	Weighted Misc & Mob (%)	Stage I Estimate with Misc & Mob (Assume Base Cost = $100)	Stage I/Actual Cost Ratio (Average)	Stage I Estimate to Actual Cost Multiplier (Average)	Actual Estimated Cost	Total Misc & Mob Required ($)	Total Required Misc & Mob (%) (Average)	Change in Current Stage I Misc & Mob (%)
Bridge (<$1 million) (n=25)	26.20%	$126.17	1.11	0.9	$113.67	$13.67	13.70%	-12.50%
Bridge ($1-4.99 million) (n=40)	29.30%	$129.33	0.73	1.37	$177.16	$77.16	77.20%	47.80%
Bridge (>$5 million) (n=10)	22.00%	$122.05	0.75	1.33	$162.73	$62.73	62.70%	40.70%
Interstate Capacity (n=2)	44.10%	$144.06	0.56	1.79	$257.24	$157.24	157.20%	113.20%
Interstate Maintenance (n=3)	35.30%	$135.31	0.51	1.96	$265.31	$165.31	165.30%	130.00%
Rural (n=9)	41.20%	$141.25	0.75	1.33	$188.33	$88.33	88.30%	47.10%
Urban (n=8)	40.90%	$140.94	0.74	1.35	$190.46	$90.46	90.50%	49.50%

Exhibit 35. Construction: Method for Determining Total Required Misc & Mob Percentages for Better Predictions of Actual Construction Project Cost

Exhibit 36 through Exhibit 43 present graphs of the current and proposed weighted Misc and Mob percentages to predict actual construction project costs. Note that, for all project types (except bridges < $1 million), the proposed Misc & Mob percentages should increase at all the estimation stages. Exhibit 43 shows the Misc & Mob weighted multipliers by estimation stage and project type. For the intermediate bridge projects ($1-$4.99 million), the current proposed weighted Misc & Mob multipliers would be 2.7, 2.7, 2.5, and 1.5 for the Stage I, Stage II, Stage III, and Stage IV estimates, respectively.

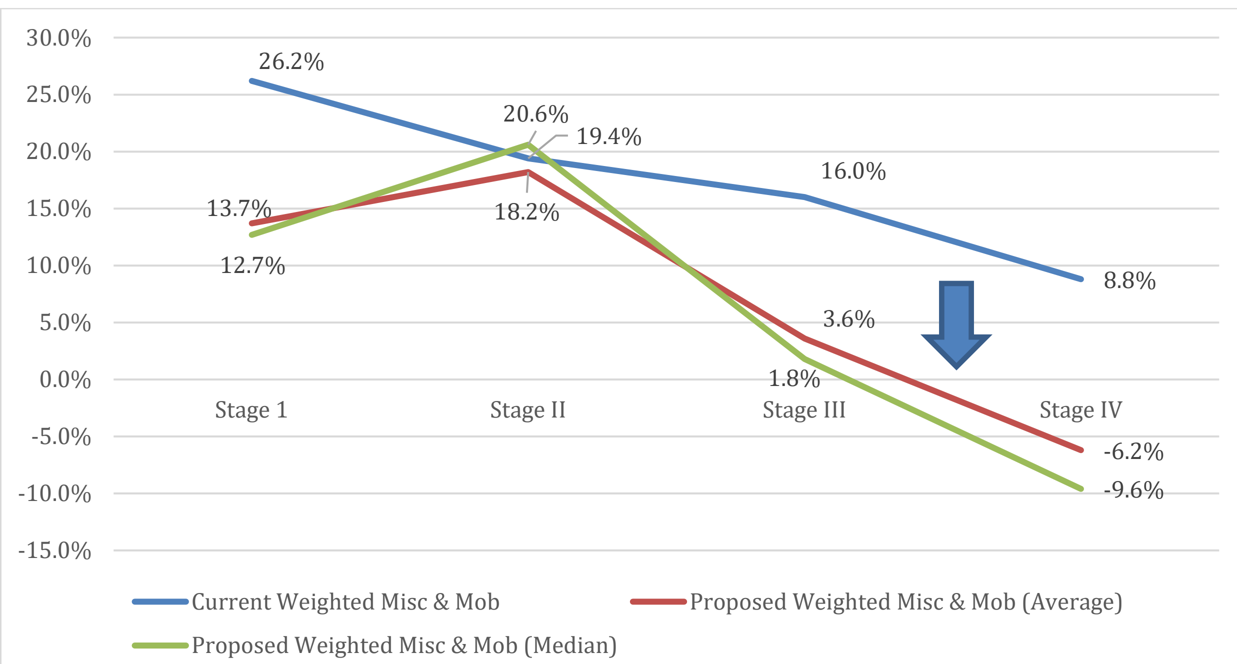


Exhibit 36. Construction: Bridges (< $1 million): Current vs Proposed Weighted Misc & Mob Percentages (n = 23)

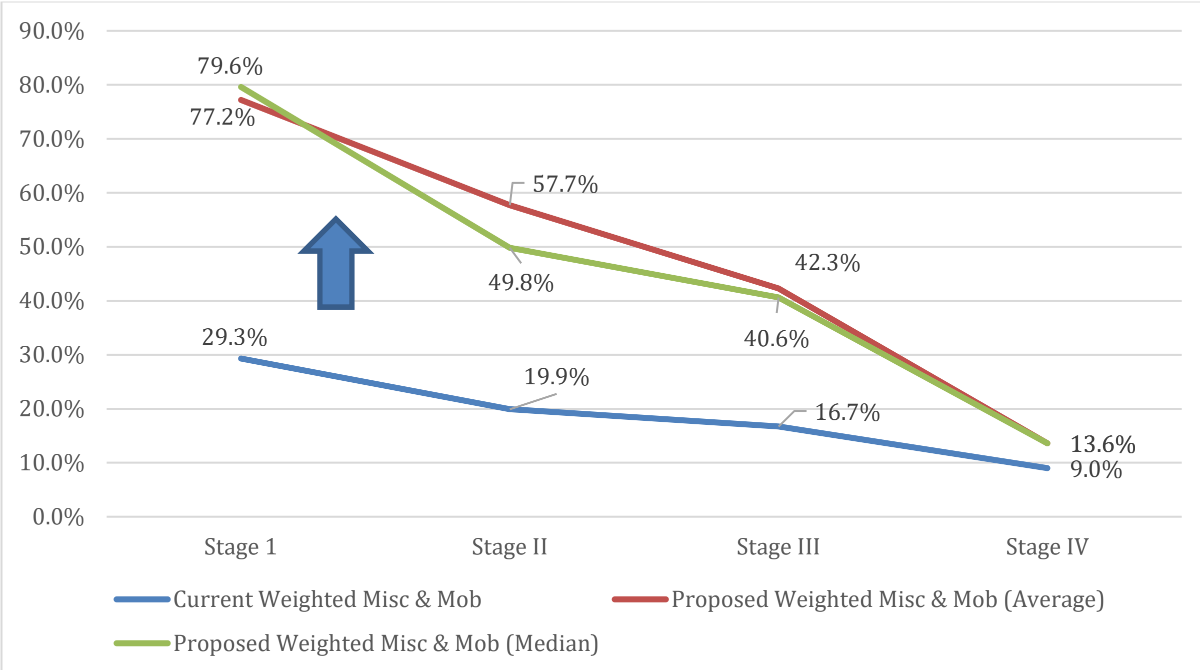


Exhibit 37. Construction: Bridges ($1-$4.99 million): Current vs Proposed Weighted Misc & Mob Percentages (n = 32)

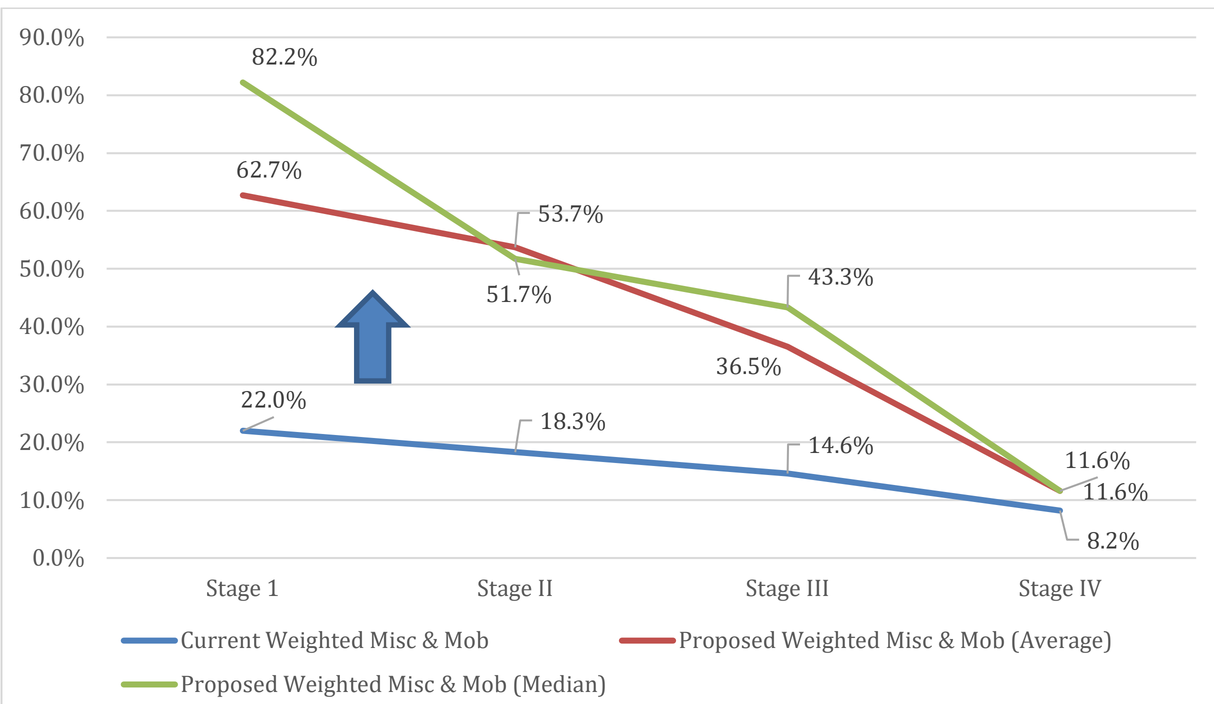


Exhibit 38. Construction: Bridges (> $5 million): Current vs. Proposed Weighted Misc & Mob Percentages (n = 10)

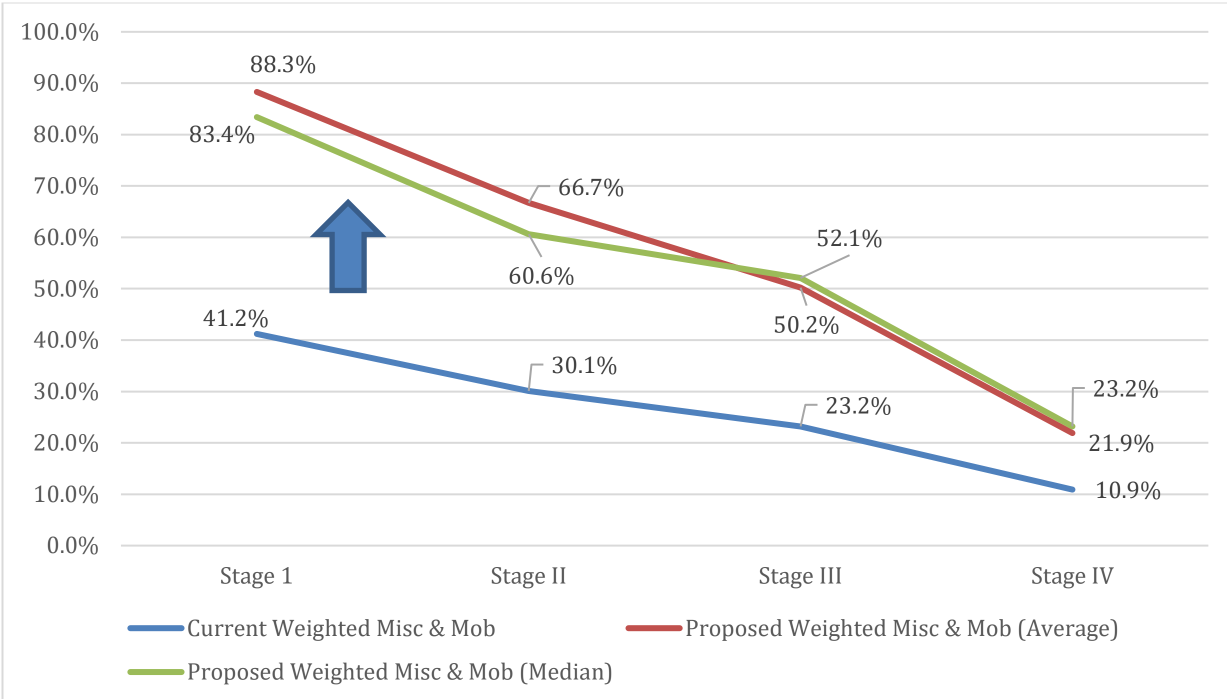


Exhibit 39. Construction: Rural Projects: Current vs. Proposed Weighted Misc & Mob Percentages (n = 6)

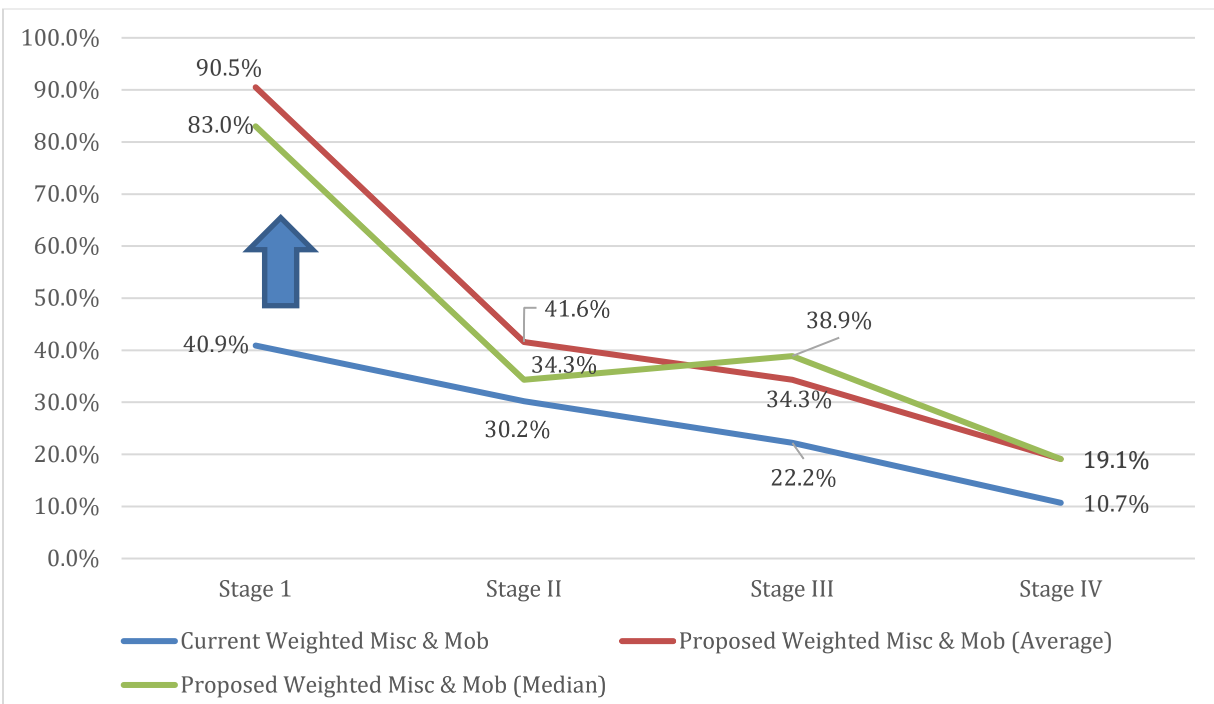


Exhibit 40. Construction: Urban Projects: Current vs. Proposed Weighted Misc & Mob Percentages (n = 8)

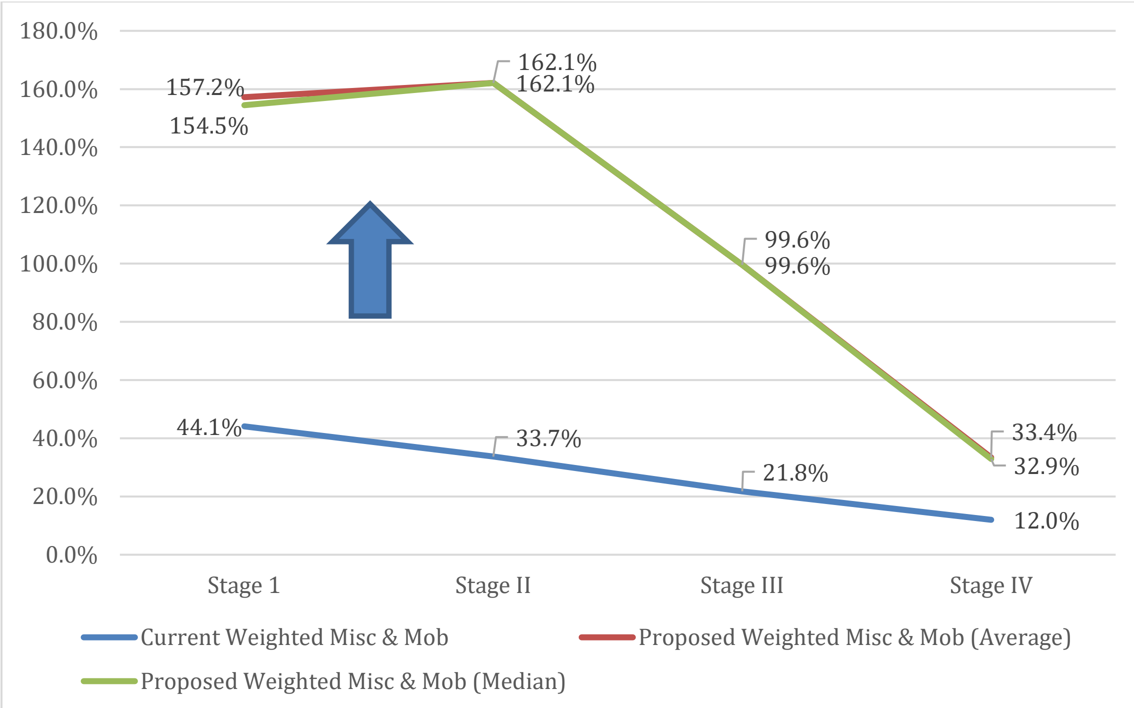


Exhibit 41. Construction: Interstate Capacity Projects: Current vs. Proposed Misc & Mob Percentages (n = 2)

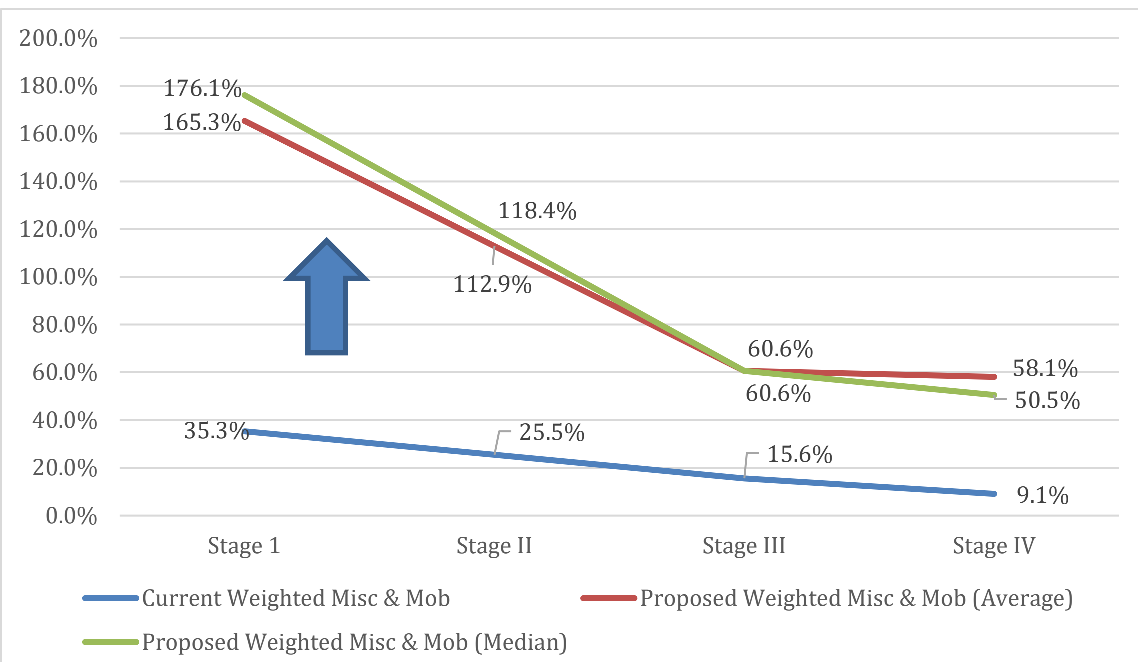


Exhibit 42. Construction: Interstate Maintenance Projects: Current vs. Proposed Weighted Misc & Mob Percentages (n = 3)

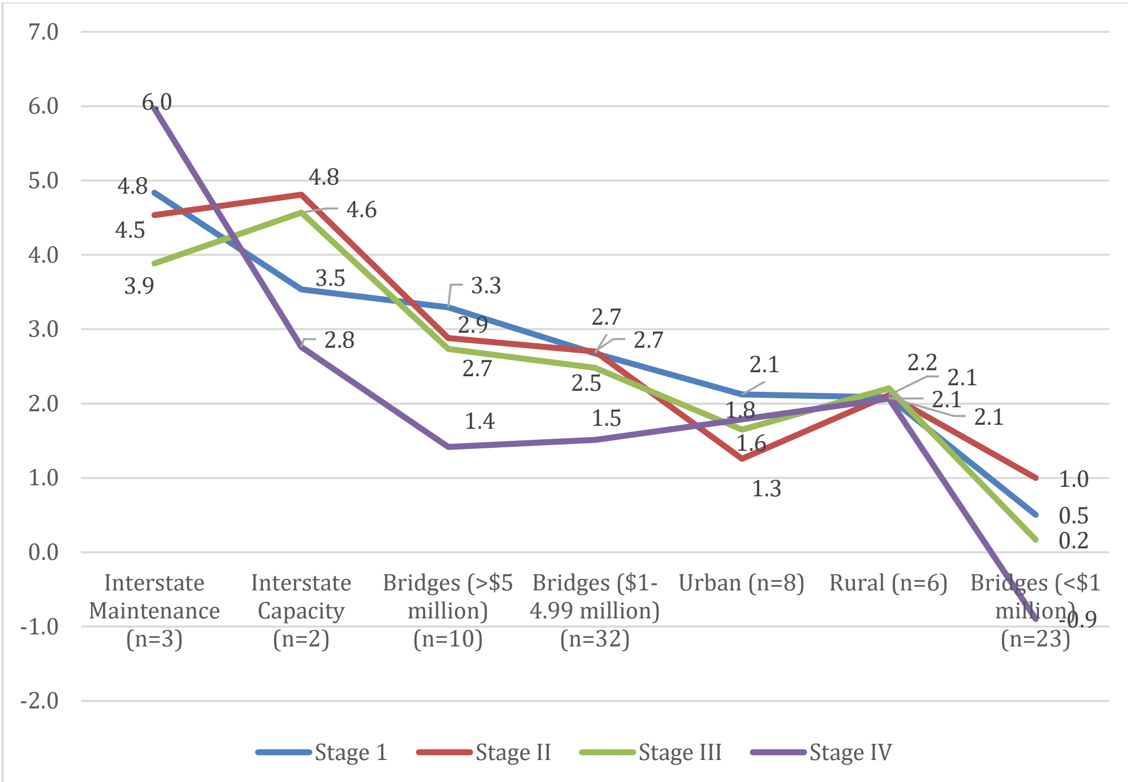
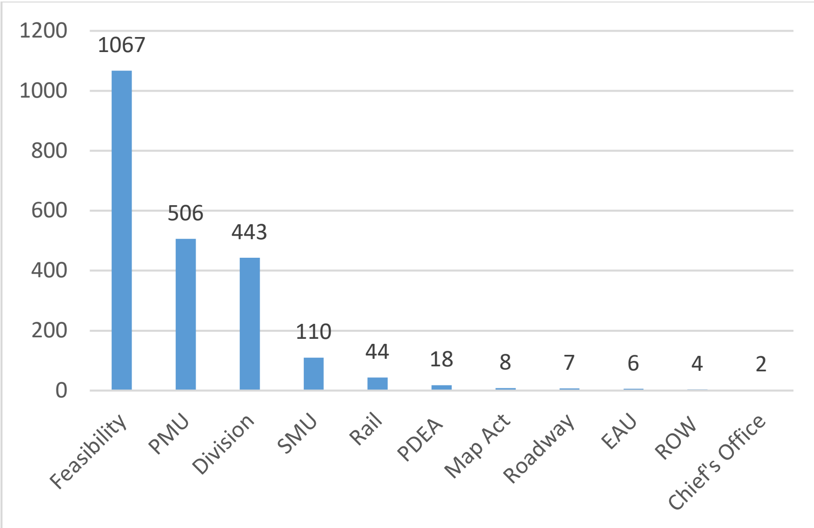


Exhibit 43. Construction: Current to Proposed Weighted Misc & Mob Multipliers Right-of-Way Project Data

General Right-of-Way Project Characteristics

From the ROW data provided, the research team was able to determine several general project characteristics. For example, approximately 2,215 ROW estimates were requested from July 29, 2014 to May 3, 2021. The amount of time allocated for each request averaged 66.5 days (29.8-day standard deviation). Also, 52 requests, or 2.3%, were designated as 'ASAP', 36% of the requests were processed on or ahead of schedule, and 64% took longer than anticipated with an average overdue time of 50 days per request. Exhibit 44 shows the number of ROW requests that came from the various NCDOT units.



Notes: PMU: Project Management Unit
SMU: Structures Management Unit
PDEA: Project Development Environment Analysis (changed to PMU)
EAU: Environmental Assessment Unit

Exhibit 44. Right-of-Way: Number of Requests by Unit

Current Right-of-Way Estimating Approach

Exhibit 45 shows the current estimating approach used by the NCDOT ROW Unit. The acquisition cost includes ROW, easement(s), improvements/damages, and consultant fees. The types of easements include aerial utility easement (AUE), temporary construction easement (TCE), permanent drainage easement (PDE), permanent utility easement (PUE), temporary utility easement (TUE), and drainage/utility easement (DUE). A 1.5 multiplier was used to create the final estimated acquisition cost. Condemnation is estimated at either 0.20 or 0.40 times the estimated acquisition cost; thus, the contingency multiplier is either 1.7 or 1.9 times the estimated acquisition cost. The estimated project cost includes relocation costs and asbestos abatement and demo costs.

RIGHT-OF-WAY ESTIMATE	Amount
Acquistion Cost	
ROW $	$ 75.00
Easement $	$ 20.00
Improvement $/Damages	$ 5.00
Estimated Acquisition	**$ 100.00**
Final Estimated Acquistion Cost (1.5 x Est. Acquisition)	$ 150.00
Estimated Condemnation Cost (0.20 or 0.40*Est. Acquisition)	$ 40.00
Final Est. Acquisition Cost plus Est. Condemnation Cost (1.7 or 1.9*Est. Acquisition)	**$ 190.00**
Estimated Relocation Cost	$ 9.00
Estimated Asbestos Abatement and Demo Cost	$ 5.00
Consultant Fees	$ 3.00
Estimated Project Cost	**$ 207.00**

Exhibit 45. Right-of-Way: Current NCDOT Estimating Approach

Right-of-Way Contingency Allowance

The effective contingency factor for ROW reflects two uncertainties: (1) uncertainties in knowing the final acquisition price (1.5 multiplier) and (2) uncertainties in knowing the possibility of condemnation (0.2 or 0.4 multiplier depending on the nature of the acquisition; e.g., a gas station may require the higher multiplier). Thus, the overall contingency multiplier for ROW is either 1.7 or 1.9 times the initial estimated acquisition cost.

Right-of-Way Data Availability

ROW cost data were provided for 234 projects from the list of 434 completed projects. Estimation data were available for 27 projects. The remaining project estimates were for older projects and thus no data were available. One estimate value along with the estimate year were provided, mostly for the feasibility and alignment-defined stages. Exhibit 46 presents sample data. Based on these data, the research team was unable to ascertain which contingency factors had been used in the estimates. Substantial differences between the estimate and the funded and expended amount are apparent.

TIP No.	Stage I Estimate	Stage II Estimate	Stage III Estimate	Total PO Value	Cost / Payments
B-5110				$23,799.85	$0.00
B-4987				$88,785.25	$0.00
B-5128				$78,890.00	$0.00
B-4832				$70,093.04	$70,093.04
B-4832				$53,861.02	$52,681.28
R-2707				$90,037.01	$0.00
R-2707				$4,719.90	$4,719.90
R-2707				$0.00	$327,103.69
R-2707				$378,846.10	$51,742.41
R-2707				$42,985.03	$3,625.34
R-2707				$0.00	$39,359.69
R-2246				$242,326.23	$0.00

Note: Utility relocation costs typically include ROW on past projects. Assumes no contingency (older projects).

Exhibit 46. Right-of-Way: Utility Relocation Cost Data (Typical)

Requirements Needed to Validate Current Right-of-Way Contingency Factors

The research team was not able to assess the contingency factors used during Stages I through III as these estimation data were not available. In order to further validate the ROW contingency factors used by the NCDOT, the ROW estimates for each stage, including the assumed contingency factor, were needed. Thus, the amount of contingency assumed in the funded amount (1.7 or 1.9 multiplier) for the provided data also would be helpful to know. The current contingency factors (1.7 or 1.9 x estimated acquisition cost) appear to be reasonable. As an alternative approach for assessing ROW contingency, the NCSU research team worked with the ROW Unit to develop a risk-based approach to determine ROW costs. Appendix B presents the results and indicates that this approach is viable for predicting ROW project costs. At this time, however, the NCDOT ROW Unit prefers to continue using its current approach to managing risk for the ROW portion of a project.

Utility Relocation Project Data

Understanding utility relocation costs is complicated because POs are not always updated and utility agreements typically do not reflect all of the relocation costs, such as tree removal and erosion control, or inflation whereby higher material costs force utility companies to change their original agreements. For these reasons, the Utilities Unit recently added a 25% contingency allowance to agreements to cover these extra expenses. However, the project data provided to the research team reflect completed projects that did not include the relatively new 25% contingency allowance. The research team also was not provided extra utility relocation-associated expenses. Project data initially provided to the research team typically included ROW and utility relocation expenses in the agreements. For newer projects, ROW and utility relocation expenses are itemized separately. A recommendation is for the NCDOT to collect data on additional costs in future projects and compare them to the 25% contingency factor that currently is being applied to utility relocation agreements.

Utility Relocation Data Availability

Many of the utility relocation projects were considered older and, as a result, ROW costs most likely were included in the utility relocation agreement costs, which can be verified by referring to the work breakdown structure (WBS) codes that include a unique five-digit project identification number followed by:

- .1 (preliminary engineering and project management costs)
- .2 (ROW and utilities)
- .2.6 (ROW)
- .2.7 (utility relocation)
- .3 (construction)

Most of the utility agreements that were provided to the research team used a .2 WBS code, signifying that both ROW and utility relocation costs were included in the agreement. However, ROW and utility relocation costs are separated on newer projects. Some projects had multiple agreements with the same utilities provider. The following information was provided:

- Total PO value
- PO number
- PO vendor
- Vendor determined
- WBS / work order
- Cost / payments
- PO close date
- Document date
- Purchase group
- Purchase group description
- Cost center
- Phase ID

Utility Relocation Agreements by Project Type

Exhibit 47 shows the distribution of unique utility relocation agreements by project type. Most of the utility relocation agreements are for rural, urban, and highway safety projects, which have on average more than one agreement. The maximum number of agreements also was found for each of these three categories.

Project Type	# Unique Utility Agreements	# Projects	# Agreements/ Projects	Min	Max
Rural	69	44	1.57	0	6
Urban	68	46	1.48	0	7
Highway Safety	20	17	1.18	0	4
Bridge (>$5 million)	21	21	1	0	3
Interstate Capacity	7	7	1	0	3
Bridge ($1-4.99 million)	110	135	0.81	0	3
Bridge (<$1 million)	64	136	0.47	0	3
Interstate Maintenance	2	28	0.07	0	1
Total	361	434	0.83	0	7

Exhibit 47. Utility Relocation: Distribution of Utility Agreements by Project Type

Exhibit 48 shows the contribution of utility relocation agreements by region and project type.

Project Type by Region	Total PO Value	Contribution (%)
Central	**$33,733,536.55**	**100.0%**
Bridge (<$1 million)	$1,971,801.72	5.8%
Bridge ($1-4.99 million)	$3,655,452.13	10.8%
Bridge (>$5 million)	$1,568,801.53	4.7%
Rural	$4,684,647.95	13.9%
Urban	$20,976,655.83	62.2%
Interstate Capacity	$0.00	0.0%
Interstate Maintenance	$14,513.86	0.0%
Highway Safety	$861,663.53	2.6%
Eastern	**$53,178,757.75**	**100.0%**
Bridge (<$1 million)	$1,378,684.44	2.6%
Bridge ($1-4.99 million)	$2,151,153.96	4.0%
Bridge (>$5 million)	$5,751,751.73	10.8%
Rural	$17,804,404.51	33.5%
Urban	$25,544,630.14	48.0%
Interstate Capacity	$0.00	0.0%
Interstate Maintenance	$86,207.73	0.2%
Highway Safety	$461,925.24	0.9%
Western	**$26,226,933.57**	**100.0%**
Bridge (<$1 million)	$1,705,751.46	6.5%
Bridge ($1-4.99 million)	$2,795,289.24	10.7%
Bridge (>$5 million)	$403,929.17	1.5%
Rural	$17,384,043.25	66.3%
Urban	$2,250,839.32	8.6%
Interstate Capacity	$1,599,677.74	6.1%
Interstate Maintenance	$0.00	0.0%
Highway Safety	$87,403.39	0.3%

Exhibit 48. Utility Relocation: Utility Agreement Contribution by Project Type and Region

Exhibit 49 shows the utility agreement contribution by region. As shown, the Eastern region of North Carolina has the highest percentage of utility relocation agreements.

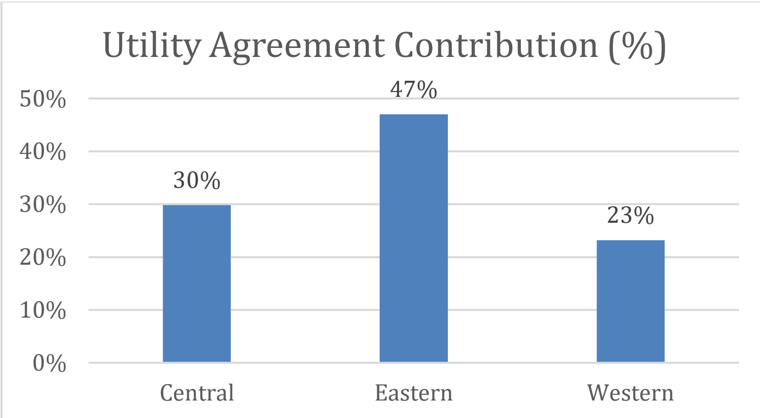


Exhibit 49. Utility Relocation: Utility Agreement Contribution by North Carolina Region

Utility Relocation Agreement Performance

Exhibit 50 provides a comparison between the cost/payments and the total PO value for utility relocation agreements by region and project type. Overall, the cost/payments are lower than the total PO value by 12% to 13% for each region.

Project Type by Region	Total PO Value	Cost / Payments	% Difference
Central	**$33,733,536.55**	**$28,875,651.12**	**-13%**
Bridge (<$1 million)	$1,971,801.72	$1,689,771.27	-12%
Bridge ($1-4.99 million)	$3,655,452.13	$2,643,664.60	-15%
Bridge (>$5 million)	$1,568,801.53	$1,391,638.21	-7%
Rural	$4,684,647.95	$4,032,268.00	-15%
Urban	$20,976,655.83	$18,282,636.03	-13%
Interstate Capacity	$0.00	$0.00	0%
Interstate Maintenance	$14,513.86	$14,513.86	0%
Highway Safety	$861,663.53	$821,159.15	-5%
Eastern	**$53,178,757.75**	**$41,862,685.77**	**-13%**
Bridge (<$1 million)	$1,378,684.44	$1,276,669.14	-10%
Bridge ($1-4.99 million)	$2,151,153.96	$1,711,444.76	-11%
Bridge (>$5 million)	$5,751,751.73	$5,580,049.02	-7%
Rural	$17,804,404.51	$15,798,877.83	-10%
Urban	$25,544,630.14	$17,015,610.90	-21%
Interstate Capacity	$0.00	$0.00	0%
Interstate Maintenance	$86,207.73	$67,361.94	-22%
Highway Safety	$461,925.24	$412,672.18	-17%
Western	**$26,226,933.57**	**$23,916,291.12**	**-12%**
Bridge (<$1 million)	$1,705,751.46	$1,376,378.32	-13%
Bridge ($1-4.99 million)	$2,795,289.24	$2,426,601.95	-14%
Bridge (>$5 million)	$403,929.17	$363,406.07	-11%
Rural	$17,384,043.25	$16,227,588.13	-6%
Urban	$2,250,839.32	$1,859,216.05	-15%
Interstate Capacity	$1,599,677.74	$1,588,999.97	-5%
Interstate Maintenance	$0.00	$0.00	0%
Highway Safety	$87,403.39	$74,100.63	-23%

Exhibit 50. Utility Relocation: Utility Agreement Cost Performance by Region and Project Type

Utilities Relocation Contingency Allowance

As of spring 2021, the NCDOT Utilities Unit began adding a 25% contingency allowance to utility relocation agreements to account for unexpected increases in utility relocation costs during the construction phase and extra owner expenses that typically are not included in utility agreements, such as tree removal and erosion control costs. The data provided for this study include past projects, and the research team assumed that no contingency allowance had been added to those older utility relocation agreements. Exhibit 51 shows the NCDOT's current contingency calculation method.

TIP Number/Utility	Utility Relocation Agreement ($)
B-2501 (Power)	$60
B-2501 (Telecom)	$40
Subtotal	$100
Contingency (25%)	$25
Total Estimate Cost	$125

Exhibit 51. Utility Relocation: Contingency Calculation

Summary

The current state of the NCDOT's estimating process for construction, ROW, and utility relocation can be summarized as follows. Construction estimates apply different contingency allowances (referred to as 'Misc & Mob') for roadway, structure, and construction utility costs. These Misc & Mob costs decrease from the feasibility study phase (Stage I) to the final PS&E stage (Stage IV). Engineering costs for design and inspection include a 3% to 5% contingency allowance. The NCDOT Utility Unit recently began adding a 25% contingency allowance to project utilities agreements to cover the possibility of higher utility relocation costs and extra work not covered, such as tree removal and erosion control. The NCDOT ROW Unit applies either a 1.7 or 1.9 multiplier to its land acquisition cost estimates to cover the possibility of higher land purchase and condemnation costs.

The main insight gleaned from the contingency analyses of the three major project components is that the current contingency allowances appear to be reasonable *as contingency*, which typically covers known risks with uncertain outcomes, also referred to as known-unknowns (e.g., the actual utility relocation cost and schedule). These risk items typically are identified in a risk register such as the NCDOT Risk Assessment Worksheet. Under the current 'funding side' model, the NCDOT reserves a portion of available funds for programming the STIP to account for inflation as well as project overruns, which effectively reduces the amount of funds available for other projects. If the NCDOT were to adopt a 'project cost side' funding model, then each estimate would provide a more accurate representation of the final project cost from the feasibility estimate stage (Stage I) to PS&E stage (Stage IV) as it would include inflation (to the bid date or year of expenditure), contingency, and management reserve. The next chapter describes the process of developing management reserve allowances (excluding inflation) that would supplement the current contingency allowance.

Developing Management Reserve Allowances for NCDOT Projects

This chapter discusses how management reserve allowances are determined for each of the three components (i.e., construction, ROW, and utility relocation) of NCDOT projects. Management reserve percentages cover the unknown-unknowns, including unforeseen costs such as scope changes during the design phase and claims and supplementary agreements during the construction phase, as discussed earlier in this report. This aspect of the research involved a first-of-its-kind empirical approach to assess reserve percentages for the three main NCDOT project components. In order to develop the reserve allowances that do not include inflation, the time differences between the estimate stages, bid letting, and final acceptance needed to be determined. Exhibit 52 depicts the timeline of estimates from Stage 1 estimating to bidding. Appendix C presents the summary statistics for the analysis of the times between the estimate stages, letting date, and acceptance date in terms of number of days.

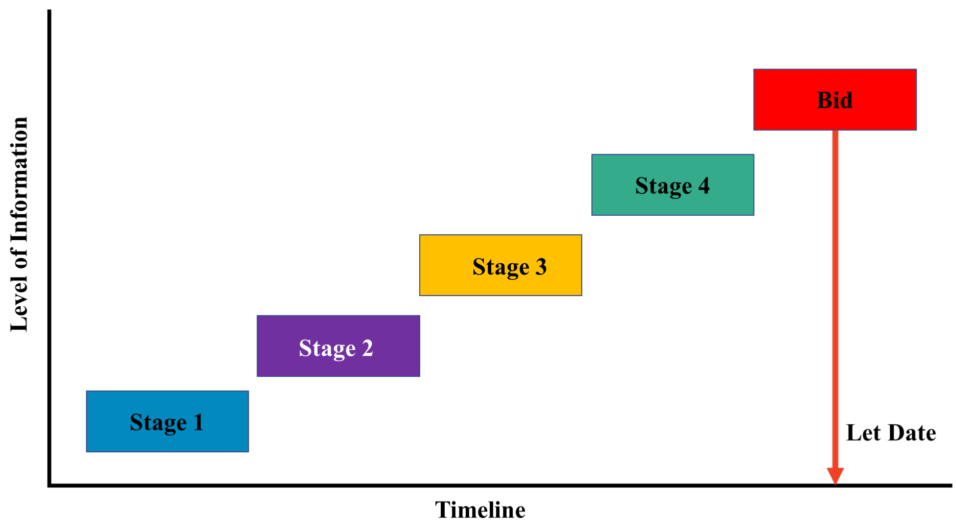


Exhibit 52. Timeline of Estimates versus Level of Information

Construction

This section focuses on developing reserve percentages for the construction portion of the project. In order to assess the appropriate reserve percentages without inflation, the estimated values must be adjusted for inflation to the year of acceptance. This analysis utilized the Construction Cost Index (CCI), published by the Engineering News-Record (ENR). Exhibit 53 shows the year-to-year CCI inflation percentages from 1997 to 2020. To adjust the estimated value, the following formula was used:

$$The\ Inflated\ Amount\ in\ the\ Desired\ Year = \frac{CCI\ Value\ in\ the\ Desired\ Year}{CCI\ Value\ in\ the\ current\ Year} \times the\ Amount\ in\ the\ current\ Year$$

For example, if an item cost $1,000 in 2003 and the CCI values are 6,695 and 11,062 in 2003 and 2018, respectively, then the same item cost (11,062/6,695) × $1,000 equals $1652.28 in 2018. After adjusting the estimated values for inflation, the reserve percentage for each stage was computed using the following formula:

$$\%\ (Actual\ Cost - Estimate\ [Stage\ X] Adjusted\ for\ inflation\ ) = \frac{(Actual\ Cost - Estimate\ [Stage\ X] Adjusted\ for\ Inflation\ )}{Estimate\ [Stage\ X] Adjusted\ for\ Inflation} \times 100$$

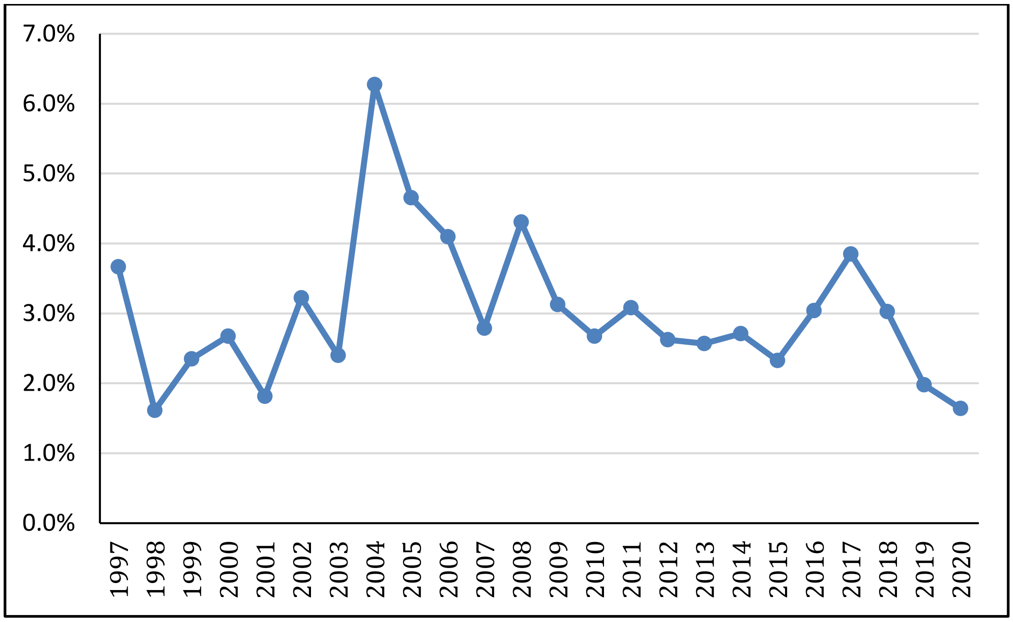


Exhibit 53. Year-to-Year Construction Cost Index Inflation Percentages from 1997 to 2020

As for the reserve percentage at the letting date, the bid amount was not adjusted for inflation. The reason for excluding the bid amount from inflation is that the contractor typically accounts for inflation in the bid. The formula for the reserve percentage at the bid stage is as follows:

$$\%\ (Actual\ Cost - Bid\ Amount\ ) = \frac{(Actual\ Cost - Bid\ Amount\ )}{Bid\ Amount} \times 100$$

Because most projects with provided estimate amounts (Stage I to Stage IV) in the database are bridge projects, bridge projects and all other project types, excluding bridge type, were grouped separately for the analysis. Furthermore, bridge projects were clustered for analysis based on bridge projects less than or equal to $1 million and greater than $1 million. The reserve percentages were then determined by taking the mean. Exhibit 54 reports the reserve percentages for bridge projects (≤ $1 million and > $1 million) and all other project types along with the number of projects (N) at each stage (i.e., Stage I to Stage IV). Note that all reserve numbers were approximated to the nearest five percent. One notable finding is that small bridge projects less than $1 million do not need reserve to be added to the estimate because the contingency allowance is adequate to cover both known-unknowns and unknowns-unknowns at all stages. It was hypothesized, practically, that the percentages would decrease from one stage to another as the amount of information and the project scope became increasingly detailed. The results presented in Exhibit 54 confirm this hypothesis. Appendix D, Exhibit D.1 presents the uncertainty quantifications for the construction reserve percentages (optimistic, most likely, and pessimistic).

Construction Estimate Reserve Stage	N	Bridge Projects <=$1 million	N	Bridge Projects >$1 million	N	All Other Projects*
Stage I	34	0%	51	35%	31	30%
Stage II	20	0%	46	25%	57	25%
Stage III	42	0%	60	15%	77	20%
Stage IV	45	0%	72	0%	125	5%

*Includes rural, urban, interstate and highway safety.

Exhibit 54. Construction Reserve Percentages at Different Estimate Stages

Because the sample size was adequate at the bid stage, the analysis was separated by project type. Exhibit 55 reports the construction reserve percentages at the bid stage. A 10% reserve allowance is recommended to be applied to the bid amount for project types not included in the analysis (e.g., rest area projects). The results presented in Exhibit 55 suggest that the actual cost of interstate projects varies from the bid amount and that such projects are riskier than the other project types. Thus, interstate projects need a higher reserve allowance to cover the unknowns-unknowns during the construction phase. On the other hand, small bridge projects that are less than $5 million are more predictable with fewer uncertainties and thus do not require any reserve. Note that all reserve allowances were approximated to the nearest five percent.

Project Type	N	Construction Phase Bid Amount Reserve
Bridge Projects (<=$5 million)	150	0%
Bridge Projects (>$5 million)	142	5%
Rural	42	5%
Urban	43	10%
Interstate	33	15%
Highway Safety	17	10%
All Others (except bridge projects)	N/A	10%

Exhibit 55. Construction Reserve Percentages at the Bid Stage

Right-of-Way

The management reserve allowances for ROW were developed similarly to those for the construction portion. However, only one estimate was provided for each project, and this estimate was considered a Stage I estimate because most ROW estimates were provided about four years on average before the letting date. The estimated amounts were then adjusted for inflation using the CCI published by the ENR, as explained in the previous section. In this case, however, the estimated ROW amounts were adjusted for inflation to the letting date in contrast to the estimated amounts for construction that were adjusted to the acceptance year of the construction project.

Because most ROW projects are bridge projects, the analysis was separated for bridge projects (N = 81) and all other project types except bridge projects (N = 40). Analysis of all other projects except bridge projects was not conducted according to specific project type (e.g., rural, urban, and interstate) due to the limited sample size. Also, the bridge ROW projects were not divided by construction project size (e.g., ≤ \$1 million and > \$1 million or ≤ \$5 million and > \$5 million) because the construction costs for these projects were not provided in the database. The reserve allowances were assessed using the following formula:

$$\% \ (Actual\ Cost - Estimate\ [Stage\ 1] adjusted\ for\ inflation\ ) = \frac{(Actual\ Cost - Estimate\ [Stage\ 1] adjusted\ for\ inflation\ )}{Estimate\ [Stage\ 1] adjusted\ for\ inflation} \times 100$$

The reserve percentages for ROW were then determined by assuming the mean value. Exhibit 56 reports the reserve percentages of ROW projects for bridge project types and all other project types along with the number of projects (N) included in the analysis. Note that all reserve numbers were approximated to the nearest five percent. Future studies should investigate the appropriate reserve percentages at other stages and should cluster the analysis by project size and potentially adjust the reserve percentages for other attributes such as project size and possibly location (e.g., coastal vs. mountain regions). Appendix D, Exhibit D.2 presents the uncertainty quantifications for the ROW reserve percentages (optimistic, most likely, and pessimistic). The most likely values are the ones that are recommended to be used.

ROW Estimate Stage (added to base plus contingency)	N	ROW Reserve Percentage (Bridge Projects)	N	ROW Reserve Percentage (All Other Projects*)
Stage I	81	85%	40	60%
Stage II	N/A	No data	N/A	No data
Stage III	N/A	No data	N/A	No data
Stage IV	N/A	No data	N/A	No data

*Includes rural, urban, interstate and highway safety.

Exhibit 56. Right-of-Way Reserve Percentages

Utility Relocation

The reserve percentages for utility relocation costs were established by following the same methodology that was conducted for construction and ROW. Most of the projects reported in the utility relocation database are bridge-type projects (56), but a limited number of other project types are also in the database, with only 12 projects available for study. Furthermore, the estimates were assumed to be all Stage I estimates as the dates of the estimates were relatively old compared to the letting date. Similar to the ROW estimates, the estimated amount for utility relocation was adjusted for inflation to the letting year of the construction project using the CCI. Unfortunately, the construction costs of the 56 bridge projects were not included in the database and thus the analysis could not be clustered by bridge project size. The reserve percentages were assessed using the following formula:

$$\%\ (Actual\ Cost - Estimate\ [Stage\ 1] adjusted\ for\ inflation\ ) = \frac{(Actual\ Cost - Estimate\ [Stage\ 1] adjusted\ for\ inflation\ )}{Estimate\ [Stage\ 1] adjusted\ for\ inflation} \times 100$$

Because the current utility relocation estimate adds 25% for contingency, this amount was subtracted from the analysis and the mean was considered to be the recommended value. Exhibit 57 reports the reserve percentages for utility relocations for bridge project types and all other project types (except bridges) along with the number of projects (N) involved in the analysis. Note that all reserve allowances were approximated to the nearest five percent. Exhibit 57 suggests that the contingency percentage for utility relocation is adequate to cover both contingency and reserve amounts and that other project types should include reserve percentages in their estimates. However, future studies should investigate whether or not this suggestion will hold for large bridge projects (i.e., bridge projects > $1 million). Also, the findings should be separated by different project types, sizes, and estimate stages. Appendix D, Exhibit D.3 presents the uncertainty quantifications for the utility relocation reserve percentages (optimistic, most likely, and pessimistic). The most likely values are the ones that are recommended to be used.

Utility Relocation Estimate Reserve Stage (added to base plus contingency	All Bridge Projects	All Other Projects**
Stage I	0%*	65%***
Stage II	No data	No data
Stage III	No data	No data
Stage IV	No data	No data

*Adding 25% contingency is sufficient; no reserve amount necessary.
**Includes rural, urban, interstate, and highway safety projects.
***Based on limited data (12 projects)

Exhibit 57. Utility Relocation Reserve Percentages

Proposed Estimating/Project Funding Model Approach

After assessing the current NCDOT estimating process for construction, ROW, and utility relocation cost estimating, this study offers an approach that allows the NCDOT to transition from a project funding side model (whereby the current STIP funding covers the costs of new and ongoing projects) to a project cost side model (whereby each project estimate provides a more accurate representation of the actual project cost). The new approach would modify the current estimating process (see Exhibit 10) to incorporate management reserve in each estimate as well as the bid amount. Exhibit 58 presents the new approach to determine the total project cost, beginning with the feasibility (Stage I) estimate through to the bidding stage. This report provides the recommended management reserve allowances for all construction estimate stages and bidding stages clustered by project type (see Exhibits 54 and 55). The report also provides the recommended reserve percentages for the ROW and utility relocation components at Stage I (see Exhibits 56 and 57, respectively). As shown in Exhibit 58, the reserve amounts for each component are multiplied by the base estimate and contingency.

ESTIMATE	Estimate				Bid Amount	Actual Cost (AC)
	Stage I	Stage II	Stage III	Stage IV		
CONSTRUCTION						
Roadway	A					
Structures	B					
Construction Utilities	C					
Base Construction Estimate	D=A+B+C					
Constuction Contingency (Misc & Mob)*	E					
Management Reserve (Construction)**	F					
Inflation (Construction)	Inflation					
Contract Cost	**G** = D + E + F + Inflation				H	I
Engineereering and Contingency (E&C)***	J					K
Total Construction Cost	**L = G + J**					
UTILITY RELOCATION	**Stage I**	**Stage II**	**Stage III**	**Stage IV**		
Base Utility Relocation Estimate	M					
Contingency (25% of Base Cost)	N					
Management Reserve (Utility Relocation)	O					
Inflation (Utility Relocation)	Inflation					
Total Utility Relocation Cost*****	**P** = M + N + O + Inflation					Q
RIGHT-OF-WAY	**Stage I**	**Stage II**	**Stage III**	**Stage IV**		
Base Right-of-Way Cost	R					
Contingency (0.7 or 0.9* Purchase Acquisition Cost)	S					
Management Reserve (Right-of-Way)	T					
Inflation (Right-of-Way)	Inflation					
Total Right-of Way Cost*****	**U** = R + S + T + Inflation					V
TOTAL PROJECT COST (TPC)	**Total Project Estimate = L + P + U**					**TPC AC = I+K+Q+V**

* Amount varies by Stage and Component

**Amount varies by Stage and Project Type; includes scope changes, claims and supplementary agreements

***Typically 15% of Contract Cost--Contingency applies to Engineering Costs only

Exhibit 58. Estimating Process that Includes Management Reserve

Note that the management reserve allowances do not include inflation. Therefore, the total project estimate at each stage should be adjusted for inflation. For the construction component, adjusting the amounts for inflation to the bid date or year of expenditure is recommended. As for ROW and utility relocation, the cost estimate should be adjusted for inflation to the letting year, as most of the ROW acquisitions and utility relocations occur within the bidding year. Adjusting the values for inflation is challenging because (1) the project let date is approximate, (2) the final acceptance date is uncertain, and (3) future inflation rates are difficult to forecast. Therefore, the NCDOT should forecast the CCI values or other economic index values using appropriate time series techniques, such as the Auto Regressive Integrated Moving Average (ARIMA). Inflation considerations in a project cost side funding model are important, and thus, the way inflation is determined and when it is introduced will need future study.

Study Limitations

The NCSU research team is grateful to the NCDOT for providing project data to perform the analyses in this study. Although the research team could provide some guidance regarding the adequacy of the contingency and management reserve allowances currently used by the NCDOT, the study has limitations, especially as they relate to the quantity and quality of the project data provided for the assessment. For example, the research team was unable to assess engineering contingency due to the lack of provided data. Furthermore, the team could not directly assess the 25% contingency allowance that is now being applied to utility relocation agreements because all of the available data were from past projects that did not include this contingency factor. For ROW and utility relocation costs, a reserve allowance could be determined only for Stage I estimates because the cost data for the other stages were not provided to the team. Future studies should assess the appropriate management reserve based on a larger pool of project data that may help in identifying differences among other project characteristics such as location, size, and type.

Conclusions & Recommendations

The purpose of this study was to assess the suitability of the contingency allowances currently used by the NCDOT for its estimates and understand ways that inflation is considered in the STIP process. The main insight gleaned from the contingency analyses of the three major project components is that the current contingency allowances appear to be reasonable *as contingency*, which typically covers known risks with uncertain outcomes. Under the current funding side model, the NCDOT reserves a portion of available funds for programming the STIP to account for inflation as well as project overruns, which effectively reduces the amount of funds available for other projects. If the NCDOT were to adopt a project cost side funding model, then each estimate would provide a more accurate representation of the final project cost from the feasibility estimate stage (Stage I) to the PS&E stage (Stage IV), as this model would include inflation, contingency, and management reserve.

The NCSU research team developed management reserve allowances for construction, ROW, and utility relocation. Because more data were provided for the construction component than the other two components, reserve allowances could be determined by construction project type for each estimate stage and for the bid amount. For ROW and utility relocation, reserve allowances could be determined only for Stage I due to data unavailability for the other stages. Exhibits 54, 56, and 57 respectively provide summaries of the recommended reserve allowances (excluding inflation) for construction, ROW, and utility relocation costs. Exhibit 55 reports the recommended reserve allowances for construction at the bid stage.

The following recommendations should lead to improvements in the NCDOT's current estimation and cost management practices as they pertain to tracking project data using a project cost side funding model.

- **Inflation**:
    - Carefully consider inflation in the estimating process. Most state DOTs include inflation of the project cost in their project estimates to the time of bid letting.
    - Forecast inflation for individual projects using a cost index such as the CCI published by the ENR.
        - For construction projects, adjust the estimate to the predicted project's acceptance date or to the year of expenditure.
        - For ROW and utility relocation projects, adjust the estimate to the predicted project letting date.
- **Management Reserve**:
    - Adopt the management reserve allowances developed in this study. Collect additional project data for Stages II to IV for ROW and utility relocation in order to determine those reserve allowances. Show reserve amounts as a separate line item in each estimate.

- **Contingency Reporting**:
    - Report base estimates and contingencies separately to make it easier for project managers to assess risks found in the Risk Assessment Worksheet and ensure that sufficient contingency allowances are included in the estimates.
- **Data Management:**
    - Investigate ways to improve data accuracy and facilitate the tracking of planned and actual project costs. For example, for utility relocations, NCDOT could consider collecting data on additional costs (e.g., tree removal and erosion control) and compare them to the 25% contingency allowance that is currently being applied to utility relocation agreements.
    - Consider setting up a project cost dashboard to collect and disseminate project data from the early feasibility phase (Stage I) of a project through completion (Stage IV), i.e., the bidding phase and project closeout. Having quick access to these data can provide useful insights for improving future project performance.
- **Estimate Performance Assessment:**
    - Reevaluate the contingency allowances and reserve allowances periodically and adjust the numbers, considering factors such as project size and location.

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Appendix A. Three Surveys of NCDOT Project Cost Estimating Practices

Appendix A presents the three online surveys that respectively target the three components of NCDOT projects: construction, right-of-way (ROW), and utility relocation. Participants were subject matter experts at diverse group of DOTs. The surveys were administered in 2021.

Appendix A.1 Survey of Project Cost Estimating Practices for Construction Contingency Allocation

Introduction:
The North Carolina Department of Transportation (NCDOT) Project Management Unit is interested in gaining a better understanding of the current estimating practices of other state transportation agencies, with a primary focus on the contingency allocation applied to project estimates at different preconstruction stages. Knowledge gleaned from this survey will provide useful ideas and practices that can be readily adopted by the NCDOT as well as other transportation agencies as they refine their cost estimating programs. This research is part of a collaborative research project between the NCDOT and North Carolina State University's (NCSU's) Institute for Transportation Research and Education (ITRE).

We ask that a person in your organization who is familiar with your organization's estimating processes, including the use of contingency factors during the different preconstruction stages, complete this survey.

Instructions:
This survey includes three sections that will help the NCSU ITRE research team learn about your background (Section A), general estimating practices (Section B), and how your organization determines appropriate levels of project contingency (Section C). This online survey is estimated to take approximately 20 minutes to complete. If you have any questions, please contact Dr. Daniel Findley (Daniel_findley@ncsu.edu) or Dr. Edward Jaselskis (ejjasels@ncsu.edu).

Consent statement:
You are being asked to complete a survey for research purposes. Completing this survey is voluntary and you can stop at any time by no longer answering the questions. You must be 18 years of age or older and reside in the United States to participate in this study. The risks associated with your participation in this survey are minimal. You will not receive compensation for completion of this survey.

If you have any questions about the survey itself, how it is implemented, or survey compensation, please contact Dr. Daniel Findley (919-515-8564, Daniel_findley@ncsu.edu) or Dr. Edward Jaselskis (ejjasels@ncsu.edu, 919-515-1158). Please refer to study number 24151.

If you have questions about your rights as a participant or are concerned with your treatment throughout the research process, please contact the NCSU Institutional Review Board at IRB-Director@ncsu.edu or 1.919.515.8754 for help.

If you consent to complete this survey, please click 'I agree' to continue. I AGREE____

Definitions

Base Estimate: "The base cost estimate value will reflect aggressive but reasonably achievable current pricing and performance. 'Aggressive but reasonably achievable' means that the assumed performance will reflect the first quartile level (i.e., P25) of historical performance or equivalent for similar strategies and scope excluding the impact of identifiable changes and risks. Estimate excludes escalation, foreign currency exchange, contingency and management reserves" (AACE 110R-20).

Contingency: "An amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs (aka, known-unknown identifiable risks). Contingency excludes major scope changes, extraordinary events, and management reserves" (AACE, RP10S-90).

Management Reserve: "An amount added to an estimate to allow for discretionary management purposes outside the defined scope of the project, or otherwise estimated. May include amounts that are within the defined scope, but for which management does not want to fund as contingency or that cannot be effectively managed using contingency. [Synonyms are reserve and reserve allowance]." (AACE 2007)

Project Cost: Base estimate + contingency + management reserve.

Construction Cost: For this survey, construction costs include roadways (excluding water and sewer) and structures.

Right-of-Way (ROW): ROW is the real property (land and improvements) and rights therein acquired for public use to construct highways for the betterment and safety of the public. ROW may be acquired through negotiated settlements or condemnation. ROW acquisition is one of the last major steps before a project is released to bidders for construction ('Right of Way Overview', NCDOT presentation).

Utility Cost: This cost includes 'wet' utility construction costs (i.e., water and sewer) and 'dry' utility relocations (e.g., power and telecommunications).

RESPONDENT INFORMATION

- What is your current title?
- Which state transportation agency do you work for?
- How long have you worked for your organization?
- How long have you estimated project costs for your organization (years)?

GENERAL CONSTRUCTION COST ESTIMATING PRACTICES

i) Provide a brief description of where you obtain data for developing your construction cost estimates.

ii) Is there a group (or groups) that manages your organization's construction cost data? If so, please provide a brief description.

- Where are construction cost data stored (e.g., Excel, Access, SAP, etc.)?
- How frequently do you update your historical construction costs?
- Do you condition your construction cost data to account for:
  - i) Timeframe (e.g., inflation escalation cost to the project mid-point)?
  - ii) Location?
  - iii) Project size (unit prices reflect economies of scale depending on the quantity)?
- Do you use proprietary or commercial software to develop your estimates (e.g., an in-house system or other software such as AASHTO cost estimating software) for construction costs?
- At project closeout, do you compare planned versus actual project costs for construction?
- Do you include a review process for estimates of construction costs?
- Please explain your organization's strengths and areas for improvement as they pertain to producing quality construction cost estimates.

PROJECT RISK QUANTIFICATION (CONTINGENCY)

Do you add a contingency allowance to your base construction estimates?

i) If yes, please identify the estimates that include contingency.
   - (1) Feasibility study estimates
   - (2) Intermediate estimates
   - (3) Final estimate

ii) If yes, which approach most closely resembles how you apply contingency allowances?
   - (1) One contingency factor for the entire base construction cost estimate.
   - (2) Different contingency factors for each main category (e.g., roadway and structure costs).
   - (3) Other (please explain).

iii) If yes, identify how you determine contingency allowances (select all that apply).
   - (1) Use a standard base contingency value that varies depending on the project scope.
     - (a) Do you adjust this factor for project-specific characteristics (e.g., complexity, amount of specialty work, location, etc.)?
     - (b) Briefly describe how you develop your contingency factors.
   - (2) Identify project-specific risks, assign probabilities and impacts for each risk, multiply the probability by the cost impact, and sum all values.
   - (3) Use risk modeling (e.g., Monte Carlo simulation).

(4) Other (please describe).

Do you include a management reserve cost as part of your overall project cost? If so, how is this cost included?

How often is your construction cost contingency reviewed and updated?

Is your project contingency linked to your risk management program? If yes, please explain how your risk management program informs the level of project contingency.

Would you be willing to allow a research team member to contact you with follow-up questions if necessary? If so, please provide your name and email address.

Thank you for your participation.

Appendix A.2 Survey of Project Cost Estimating Practices Regarding Right-of-Way Contingency Allocation

Introduction:

The North Carolina Department of Transportation (NCDOT) Project Management Unit is interested in gaining a better understanding of the current estimating practices of other state transportation agencies, with a primary focus on the contingency allocation applied to project estimates at different preconstruction stages. Knowledge gleaned from this survey will provide useful ideas and practices that can be readily adopted by the NCDOT as well as other transportation agencies as they refine their cost estimating programs. This research is part of a collaborative research project between the NCDOT and North Carolina State University's (NCSU's) Institute for Transportation Research and Education (ITRE).

We ask that a person in your organization who understands your organization's estimating processes, including the use of contingency factors during the different preconstruction stages, complete this survey.

Instructions:

This survey includes three sections that will help the NCSU ITRE research team learn about your background (Section A), general estimating practices (Section B), and how you determine appropriate levels of project contingency (Section C). This online survey is estimated to take approximately 20 minutes to complete. If you have any questions, please contact Dr. Daniel Findley (Daniel_findley@ncsu.edu) or Dr. Edward Jaselskis (ejjasels@ncsu.edu).

Consent statement:

You are being asked to complete a survey for research purposes. Completing this survey is voluntary and you can stop at any time by no longer answering the questions. You must be 18 years of age or older and reside in the United States to participate in this study.

The risks associated with your participation in this survey are minimal. You will not receive compensation for completion of this survey.

If you have any questions about the survey itself, how it is implemented, or survey compensation, please contact Drs. Daniel Findley (919-515-8564, Daniel_findley@ncsu.edu) or Edward Jaselskis (ejjasels@ncsu.edu, 919-515-1158). Please refer to study number 24151.

If you have questions about your rights as a participant or are concerned with your treatment throughout the research process, please contact the NCSU Institutional Review Board at IRB-Director@ncsu.edu or 1.919.515.8754 for help.

If you consent to complete this survey, please click 'I agree' to continue.

I AGREE____

Definitions

Base Estimate: "The base cost estimate value will reflect aggressive but reasonably achievable current pricing and performance. 'Aggressive but reasonably achievable' means that the assumed performance will reflect the first quartile level (i.e., P25) of historical performance or equivalent for similar strategies and scope excluding the impact of identifiable changes and risks. Estimate excludes escalation, foreign currency exchange, contingency and management reserves" (AACE 110R-20).

Contingency: "An amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs (aka, known-unknown identifiable risks). Contingency excludes major scope changes, extraordinary events, and management reserves" (AACE, RP10S-90).

Management Reserve: "An amount added to an estimate to allow for discretionary management purposes outside the defined scope of the project, or otherwise estimated. May include amounts that are within the defined scope, but for which management does not want to fund as contingency or that cannot be effectively managed using contingency. [Synonyms are reserve and reserve allowance]." (AACE 2007)

Project Cost: Base estimate + contingency + management reserve.

Construction Cost: For this survey, construction costs include roadways (excluding water and sewer) and structures.

Right-of-Way (ROW): ROW is the real property (land and improvements) and rights therein acquired for public use to construct highways for the betterment and safety of the public. ROW may be acquired through negotiated settlements or condemnation. ROW acquisition is one of the last major steps before a project is released to bidders for construction ('Right of Way Overview', NCDOT presentation).

Utility Cost: This cost includes 'wet' utility construction costs (i.e., water and sewer) and 'dry' utility relocations (e.g., power and telecommunications).

RESPONDENT INFORMATION

- What is your current title?
- Which state transportation agency do you work for?
- How long have you worked for your organization?
- How long have you estimated project costs for your organization (years)?

GENERAL ROW COST ESTIMATING PRACTICES

Provide a brief description of where you obtain data for developing your ROW cost estimates.

Is there a group (or groups) that manage your organization's ROW cost data? If so, please provide a brief description.

Where are ROW cost data stored (e.g., Excel, Access, SAP, etc.)?

How frequently do you update your historical ROW costs?

Do you condition your ROW cost data to account for:

1. Timeframe (e.g., inflation escalation cost to the project mid-point)?
2. Location?
3. Project size (unit prices reflect economies of scale depending on the quantity)?

Do you use proprietary or commercial software to develop your ROW cost estimates (e.g., an in-house system or other software such as AASHTO cost estimating software)?

At project closeout, do you compare planned versus actual project costs for ROW?

Do you include a review process for estimates of ROW costs?

Please explain your organization's strengths and areas for improvement as they pertain to producing quality ROW cost estimates.

PROJECT RISK QUANTIFICATION (CONTINGENCY)

Do you add a contingency allowance to your base ROW estimates?

- iv) If yes, please identify which estimates include contingency.
  - (1) Feasibility study estimates
  - (2) Intermediate estimates
  - (3) Final estimate
- v) If yes, which approach most closely resembles how you apply contingency.
  - (1) One contingency factor for the entire base ROW cost estimate.
  - (2) Different contingency factors for each main category (e.g., land cost, condemnation costs, etc.).
  - (3) Other (please explain).
- vi) If yes, identify how you determine contingency allowances (select all that apply).
  - (1) Use a standard base contingency value that varies depending on the project scope.
    - (a) Do you adjust this factor for project-specific characteristics (e.g., complexity, amount of specialty work, location, etc.)?
    - (b) Briefly describe how you develop your contingency factors.
  - (2) Identify project-specific risks, assign probabilities and impacts for each risk, multiply the probability by the cost impact, and sum all values.
  - (3) Use risk modeling (e.g., Monte Carlo simulation).
  - (4) Other (please describe).

Do you include a management reserve cost as part of your overall project cost? If so, how is this cost inclusion accomplished?

How often is your ROW contingency reviewed and updated?

Is your project contingency linked to your risk management program? If yes, please explain how your risk management program informs the level of project contingency.

Would you be willing to allow a research team member to contact you with follow-up questions if necessary? If so, please provide your name and email address.

Thank you for your participation.

Appendix A.3 Survey of Project Cost Estimating Practices for Utility Contingency Allocation

Introduction:

The North Carolina Department of Transportation's Project Management Unit is interested in better understanding the current estimating practices of other state transportation agencies with a primary focus on contingency allocation applied to project estimates at different preconstruction stages. Knowledge from this survey will provide useful ideas and practices that can be readily adopted by the NCDOT as well as other transportation agencies as they refine their cost estimating programs. As such, we would like to have someone complete this survey who understands your organization's estimating processes including the use of contingency factors during the different preconstruction stages. This research is part of a collaborative research project between the NCDOT and North Carolina State University's (NCSU) Institute for Transportation Research and Education (ITRE).

Instructions:

This survey includes three sections that will help the NCSU ITRE research team learn about your background (Section A), general estimating practices (Section B), and how you determine appropriate levels of project contingency (Section C). This online survey is estimated to take approximately 20 minutes to complete. If you have any questions, please contact Drs. Daniel Findley (Daniel_findley@ncsu.edu) or Edward Jaselskis (ejjasels@ncsu.edu).

Consent statement:

You are being asked to complete a survey for research purposes. Completing this survey is voluntary and you can stop at any time by no longer answering the questions. You must be 18 years of age or older to participate in this study. In order to participate in this study, you must reside in the United States.

There are minimal risks associated with your participation in this survey. You will not receive compensation for completion of this survey.

If you have any questions about the survey itself, how it is implemented, or survey compensation, please contact Drs. Daniel Findley (919-515-8564, Daniel_findley@ncsu.edu) or Edward Jaselskis (ejjasels@ncsu.edu, 919-515-1158). Please refer to study number 24151.

If you have questions about your rights as a participant or are concerned with your treatment throughout the research process, please contact the NC State University IRB at IRB-Director@ncsu.edu or 1.919.515.8754 for help.

If you consent to complete this survey, please click "I agree" to continue.

I AGREE____

Definitions

Base Estimate: "The base cost estimate value will reflect aggressive but reasonably achievable current pricing and performance. "Aggressive but reasonably achievable" means that the assumed performance will reflect the first quartile level (i.e., p25) of historical performance or equivalent for similar strategies and scope excluding the impact of identifiable changes and risks. Estimate excludes escalation, foreign currency exchange, contingency and management reserves" (AACE 110R-20).

Contingency: "An amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs (aka, known-unknown identifiable risks). Contingency excludes major scope changes, extraordinary events, and management reserves" (AACE, RP10S-90).

Management Reserve: "An amount added to an estimate to allow for discretionary management purposes outside the defined scope of the project, or otherwise estimated. May include amounts that are within the defined scope, but for which management does not want to fund as contingency or that cannot be effectively managed using contingency. [Synonyms are reserve and reserve allowance]." (AACE 2007).

Project Cost: Base estimate + contingency + management reserve.

Construction Cost: For this survey, construction costs include roadway (excluding water and sewer) and structures.

Right-of-Way (ROW): ROW is the real property (land and improvements) and rights therein acquired for public use to construct highways for the betterment and safety of the public. Right of Way may be acquired through negotiated settlements or condemnation. It is one of the last major steps before a project is released to bidders for construction ('Right of Way Overview' NCDOT presentation).

Utility Cost: Includes 'wet' utility construction costs (i.e., water and sewer) and 'dry' utility relocations (e.g., power and telecommunications).

RESPONDENT INFORMATION

What is your current title?

Which state transportation agency do you work for?

How long have you worked for your organization?

How long have you estimated project costs for your organization (years)?

GENERAL COST ESTIMATING PRACTICES

Provide a brief description of where you obtain data for developing your utilities cost estimates.

Is there a group (or groups) that manage your organization's utilities cost data? If so, please provide a brief description.

Where are utilities cost data stored (e.g., Excel, Access, SAP, etc.)?

How frequently do you update your historical utilities cost data?

Do you condition your utilities cost data to account for:

1. Timeframe (e.g., inflation escalation cost to the project mid-point)?
2. Location?
3. Project size (unit prices reflect economies of scale depending on the quantity)?

Do you use proprietary or commercial software to develop your utilities cost estimates (e.g., in-house system or other software such as AASHTO cost estimating software)?

At project closeout, do you compare planned versus actual project costs for utilities?

Do you include a review process for estimates of utilities costs?

Please explain your organization's strengths and areas for improvement as they pertain to producing quality utilities cost estimates.

PROJECT RISK QUANTIFICATION (CONTINGENCY)

Do you add contingency to your base utility estimates?

vii) If yes, please identify which estimates include contingency.

(1) Feasibility study estimates

(2) Intermediate estimates

(3) Final estimate

viii) If yes, which approach most closely resembles how you apply contingency.

(1) One contingency factor for the entire base utility cost estimate.

(2) Different contingency factors for each main category (e.g., water, sewer, power, telecommunications costs, etc.).

(3) Other (please explain).

ix) If yes, identify how you determine contingency (select all that apply).

(1) Use a standard base contingency value that varies depending on the project scope.

(a) Do you adjust this factor for project-specific characteristics (e.g., complexity, amount of specialty work, location, etc.)?

(b) Briefly describe how you develop your contingency factors.

(2) Identify project-specific risks, assign probabilities and impacts for each risk, multiply the probability by the cost impact, and sum all values.

(3) Use risk modeling (e.g., Monte Carlo simulation).

(4) Other (please describe).

Do you include a management reserve cost as part of your overall project cost? If so, how is this cost included?

How often is your utilities cost contingency allowance process reviewed and updated?

Is your project contingency linked to your risk management program? If yes, please explain how your risk management program informs the level of project contingency.

Would you be willing to allow a research team member to contact you with follow-up questions if necessary? If so, please provide your name and email address.

Thank you for your participation.

Appendix B. Probabilistic Approach for Assessing Right-of-Way Contingencies

Appendix B presents a probabilistic estimating approach for determining contingency allowances for Right-of-Way. This method was considered since there is a significant amount of variability between the estimated and actual ROW costs due to uncertainty primarily related to the actual land acquisition and condemnation costs.

Introduction and Assumptions

This appendix presents an alternative approach for establishing contingency requirements for right-of-way (ROW) costs. Using probabilistic risk-based estimating, three-point estimates (pessimistic, most likely, and optimistic) for land acquisition and condemnation costs are used in Monte Carlo simulations to help identify contingency allowances within a certain risk tolerance. This method is well suited for predicting ROW costs given the high level of uncertainty, especially as such uncertainty pertains to final land acquisition costs and condemnations. This approach was pilot tested during NCDOT Project R-2588B.

The major parts of a total ROW estimate are:

- Acquisition cost
- Condemnation cost
- Relocation cost
- Asbestos abatement and demolition (demo) cost

The total ROW cost is estimated using the following formula:

Total ROW cost = final estimated acquisition cost + estimated condemnation cost + estimated relocation cost + estimated asbestos abatement and demo cost in which:

- Final estimated acquisition cost = Estimated acquisition cost × 1.5
- Estimated condemnation cost = Estimated acquisition cost x 0.2 or 0.4 (depending on circumstances)
- Estimated relocation cost (for some parcels)
- Estimated asbestos abatement and demo cost (for some parcels)

The current NCDOT practice accounts for contingency, consultant fees, and inflation costs by adding 50% of the estimated acquisition cost to the total estimate (i.e., using the 1.5 factor). This amount is estimated to be nearly 25% of the total ROW cost whereby if the total ROW cost equals $13,177,901, then the contingency allowance equals $3,301,552.94. Also, the NCDOT does not estimate the condemnation cost as a separate cost item but instead multiplies the estimated acquisition cost (i.e., the estimated acquisition cost before adding the contingency factor) by 0.4 (0.2 × 2).

The acquisition cost for each parcel is estimated using the following formula. Note that the types of easements abbreviated in the formula are as follows: temporary construction easement (TCE), drainage/utility easement (DUE), permanent utility easement (PUE), permanent drainage easement (PDE), aerial utility easement (AUE), and temporary utility easement (TUE).

ROW$ + TCE$ + DUE$ + PUE$ + PDE$ + AUE$ + TUE$ + Improvement $ / Damages Est + Est Consultant $

where

- ROW$ = ROW area (acres) × estimated land parcel per acre (Est Land P/Ac)
- TCE$ = TCE area (acres) × Est Land P/Ac × 0.35
- DUE$ = DUE area (acres) × Est Land P/Ac
- PUE$ = PUE area (acres) × Est Land P/Ac
- PDE$ = PDE area (acres) × Est Land P/Ac
- AUE$ = AUE area (acres) × Est Land P/Ac
- TUE$ = TUE area (acres) × Est Land P/Ac
- Improvement $ / Damages Est is estimated separately for each parcel.
- Est Consultant $ equals zero for all parcels.

Note that 'Est Land P/Ac' is not included in the estimated acquisition cost as a stand-alone item.

In this report, the North Carolina State University (NCSU) research team proposes obtaining the contingency amount based on the probabilistic estimation process instead of multiplying the estimated acquisition cost by 1.5 (which is the current NCDOT practice). In order to construct a probabilistic estimate by utilizing triangular, normal, or any other distribution, three estimates (optimistic, most likely, and pessimistic) were created for the following items:

1. Estimated Land Parcel/Acre
2. Improvement $ / Damages Est
3. Estimated relocation cost
4. Estimated asbestos abatement and demo cost
5. Condemnation percentages
6. Contingency factors

For the first four items, the NCDOT estimates are considered as the 'most likely' values. The 'optimistic' values are obtained by multiplying the NCDOT's estimate by 0.75 and the 'pessimistic' values are found by multiplying the NCDOT's estimate by 1.5. For the condemnation cost, the percentages of 0.3, 0.4, and 0.5 are assumed for the optimistic, most likely, and pessimistic values, respectively. With regard to the contingency factors, the current NCDOT practice assumes that 1.5 is multiplied by the estimated acquisition cost to obtain the final acquisition cost. The research team devised the factors 1.25, 1.5, and 1.7 to represent the three scenarios (i.e., optimistic, most likely, and pessimistic).

Based on the three-point estimates, the research team created the probabilistic estimates by leveraging two distributions, triangular and normal. The following sections provide details regarding the generation of the probabilistic estimates and the findings obtained using these two distribution types.

Probabilistic Cost Estimation Approach: Triangular Distribution

- For the estimated acquisition cost of each of 125 parcels, assume the triangular distribution and generate Monte Carlo draws from the triangular distribution individually.
  - Sum each Monte Carlo draw from the 125 parcels to find the estimated acquisition cost distribution.
- For the estimated condemnation cost, generate the triangular distribution for the following factors: 0.3, 0.4, and 0.5 (optimistic, most likely, and pessimistic estimates, respectively).
  - Select the percentile (e.g., P85) and multiply it by the selected acquisition cost percentile to find the estimated acquisition cost distribution.
- For the estimated relocation cost, assume the triangular distribution for each of the 14 parcels with an estimated relocation cost and generate Monte Carlo draws from the triangular distribution individually.
  - Sum each Monte Carlo draw from the 14 parcels to find the estimated relocation cost distribution.
- For the estimated asbestos abatement and demo costs of the four parcels, assume the triangular distribution and generate Monte Carlo draws from the triangular distribution individually.
  - Sum each Monte Carlo draw from the four parcels to find the estimated asbestos abatement and demo cost.
- For the contingency factor, generate the triangular distribution for the following factors: 1.25, 1.5, and 1.7 (optimistic, most likely, and pessimistic estimates, respectively). 1.2 and 1.7 were selected subjectively, whereas the 1.5 × the acquisition cost is the current NCDOT practice. Select the percentile, e.g., P85, and multiply it by the selected acquisition cost percentile.
- Note:
  - P80 means that 80% of the sorted data in ascending order is less than the P80 value. Similarly, P30 is the value at which 30% of the sorted data in ascending order is less than the P30 value.
  - Theoretically, given the three-point estimates, P80 indicates that the likelihood is 80% that the item's cost will be less than the P80 value and the likelihood is 20% that the cost will be more than the P80 value.
  - Parcels 97, 98, and 102 were given Estimated Land P/Ac values; however, these parcels were not included in the cost estimate.
  - The estimate includes 125 parcels. Out of the 125 parcels, 14 parcels have an estimated relocation cost item and four parcels have an estimated asbestos abatement and demo item.
  - 100,000 Monte Carlo draws were generated; the seed number was set to 22 to ensure exact replications of the simulation.

Major Cost Item 1: Estimated acquisition cost distribution

- Assume triangular distribution for the 125 parcels and generate Monte Carlo draws from the triangular distribution individually. Exhibit B.1 shows the probability density function (PDF) and cumulative density function (CDF) distributions for the estimated land acquisition cost. Exhibit B.2 shows a table of the estimated values by percentile.

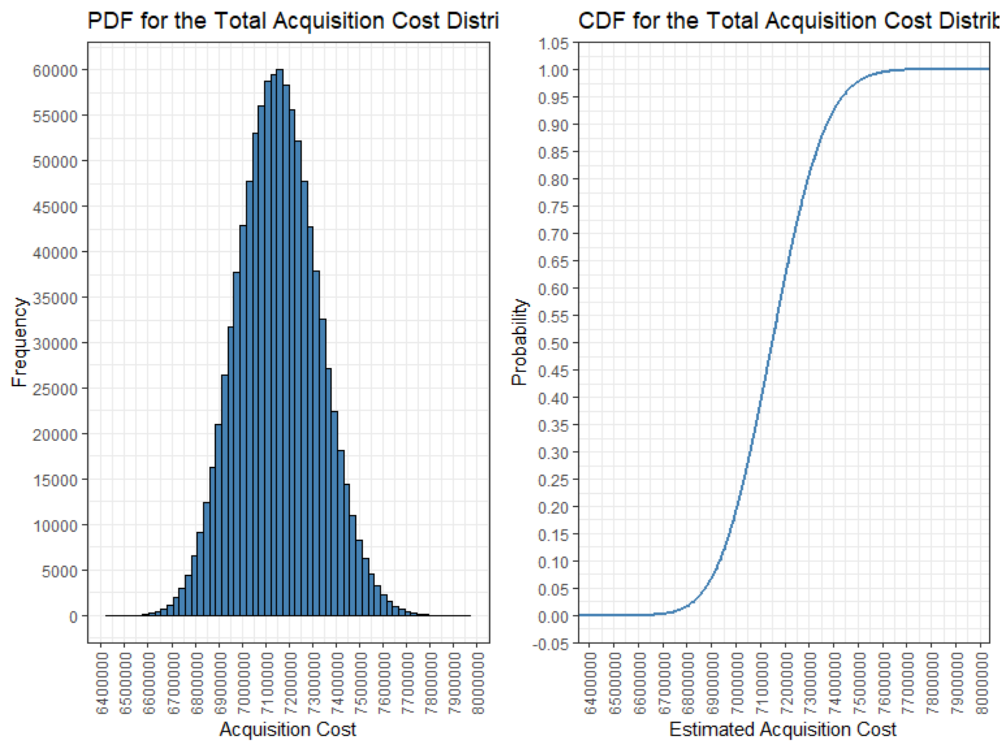

Exhibit B.1 Probability and Cumulative Density Functions for Acquisition Cost (Triangular Distribution)

Percentile (P)	Acquisition Cost Percentile - Triangular
5	6877498
10	6935630
15	6975641
20	7007642
25	7035858
30	7060912
35	7084625
40	7107116
45	7128913
50	7150723

Exhibit B.2 Acquisition Costs by Percentile (Triangular Distribution)

Major Cost Item 2: Condemnation cost percentage distribution

- For the condemnation cost, the current NCDOT practice assesses the cost item as a percentage of the acquisition cost, which is multiplied by 0.4. Thus, a triangular distribution is generated for the following factors: 0.3, 0.4, and 0.5 (optimistic, most likely, and pessimistic estimates, respectively). The estimator then selects the percentile (e.g., P85) and multiplies it by the selected acquisition cost to obtain the total condemnation cost. Exhibit B.3 shows the PDF and CDF distributions for the estimated condemnation cost. Exhibit B.4 shows a table of estimated values by percentile.

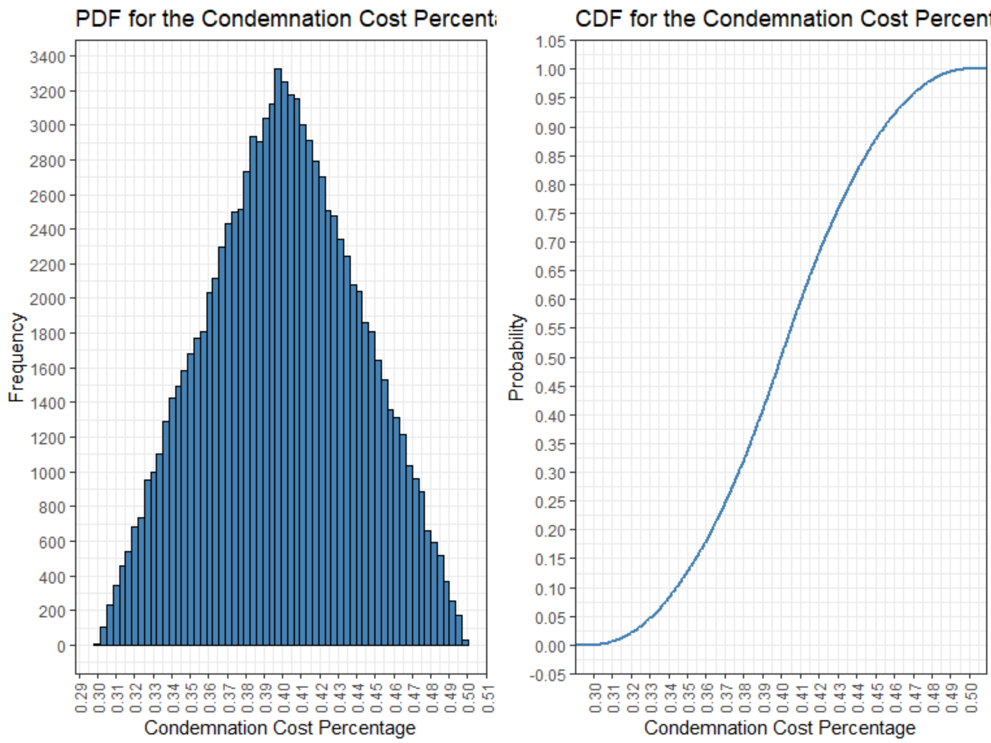

Exhibit B.3 Probability and Cumulative Density Functions for Condemnation Cost (Triangular Distribution)

Percentile (P)	Condemnation Percentage Percentile - Triangular
5	0.3315948
10	0.3444578
15	0.3547368
20	0.363417
25	0.3707467
30	0.3775361
35	0.3837535
40	0.3894587
45	0.3949694
50	0.4000723

Exhibit B.4 Condemnation Costs by Percentile (Triangular Distribution)

Major Cost Item 3: Estimated utilities relocation cost distribution

- Assume triangular distribution for the 14 parcels with estimated relocation costs and generate Monte Carlo draws from the triangular distribution individually. Sum each Monte Carlo draw from the 14 parcels to find the estimated relocation cost. Exhibit B.5 shows the PDF and CDF distributions for the estimated relocation cost. Exhibit B.6 shows a table of estimated values by percentile.

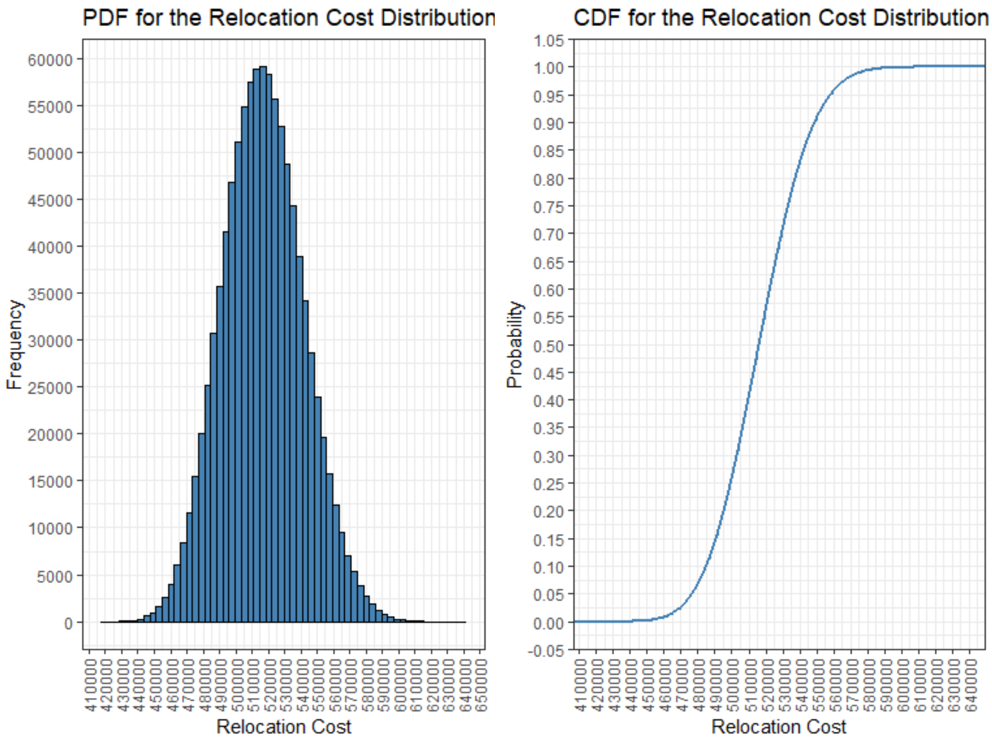

Exhibit B.5 Probability and Cumulative Density Functions for Utility Relocation Cost (Triangular Distribution)

Percentile (P)	Relocation Cost Percentile - Triangular
5	476768
10	485041.6
15	490811.5
20	495461.7
25	499496.1
30	503159.9
35	506594.4
40	509884.1
45	513077.8
50	516241.4

Exhibit B.6 Utility Relocation Costs by Percentile (Triangular Distribution)

Major Cost Item 4: Asbestos abatement and demolition cost distribution

- Assume triangular distribution for the four parcels with the estimated asbestos abatement and demo cost and generate Monte Carlo draws from the triangular distribution individually. Sum each Monte Carlo draw from the four parcels to find the asbestos abatement and demo cost distribution. Exhibit B.7 shows the PDF and CDF distributions for the estimated asbestos abatement and demolition cost. Exhibit B.8 shows a table of estimated values by percentile.

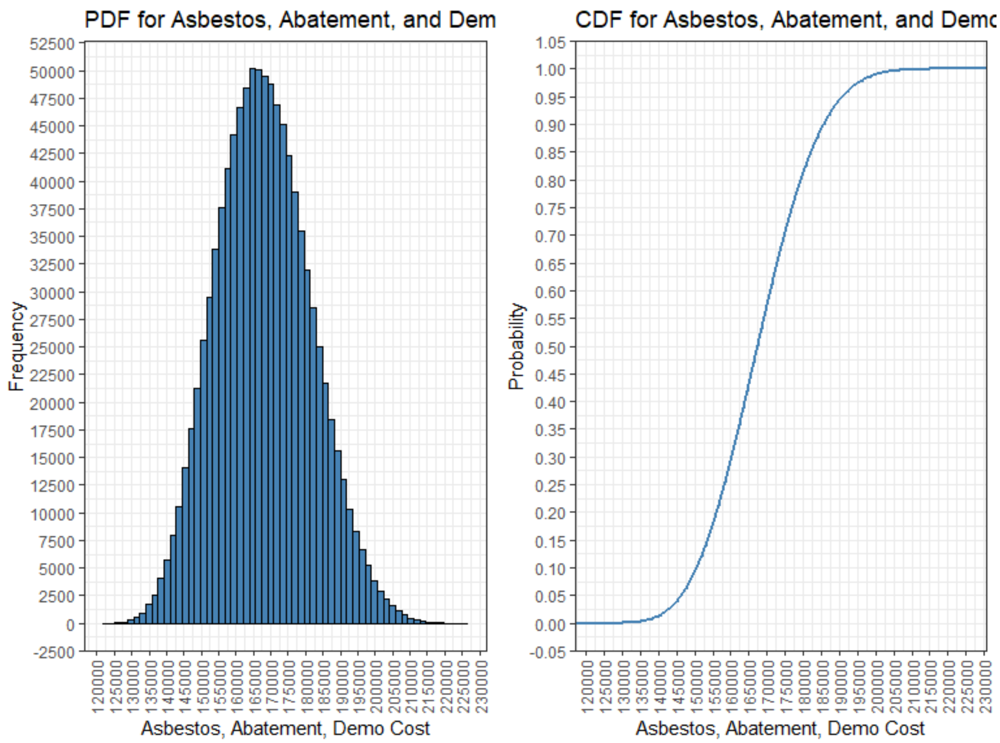

Exhibit B.7 Probability and Cumulative Density Functions for Asbestos Abatement and Demolition Cost (Triangular Distribution)

Percentile (P)	Asbestos, Abatement, and Demo Percentile - Triangular
5	146426.2
10	150665.7
15	153687
20	156155.9
25	158328.7
30	160311.2
35	162183.2
40	163988.3
45	165729.7
50	167478.7

Exhibit B.8 Asbestos Abatement and Demolition Costs by Percentile (Triangular Distribution)

Major Cost Item 5: Contingency, inflation, and consultant allowances

- For the contingency allowance, generate the triangular distribution for the following factors: 1.25, 1.5, and 1.7 (optimistic, most likely, and pessimistic estimates, respectively). 1.25 and 1.7 were selected subjectively, whereas the 1.5 × the acquisition cost represents the current NCDOT practice. Select the percentile (i.e., P85) and multiply it by the selected acquisition cost. Exhibit B.9 shows the PDF and CDF distributions for the estimated contingency, inflation, and consultant costs. Exhibit B.10 shows a table of estimated values by percentile.

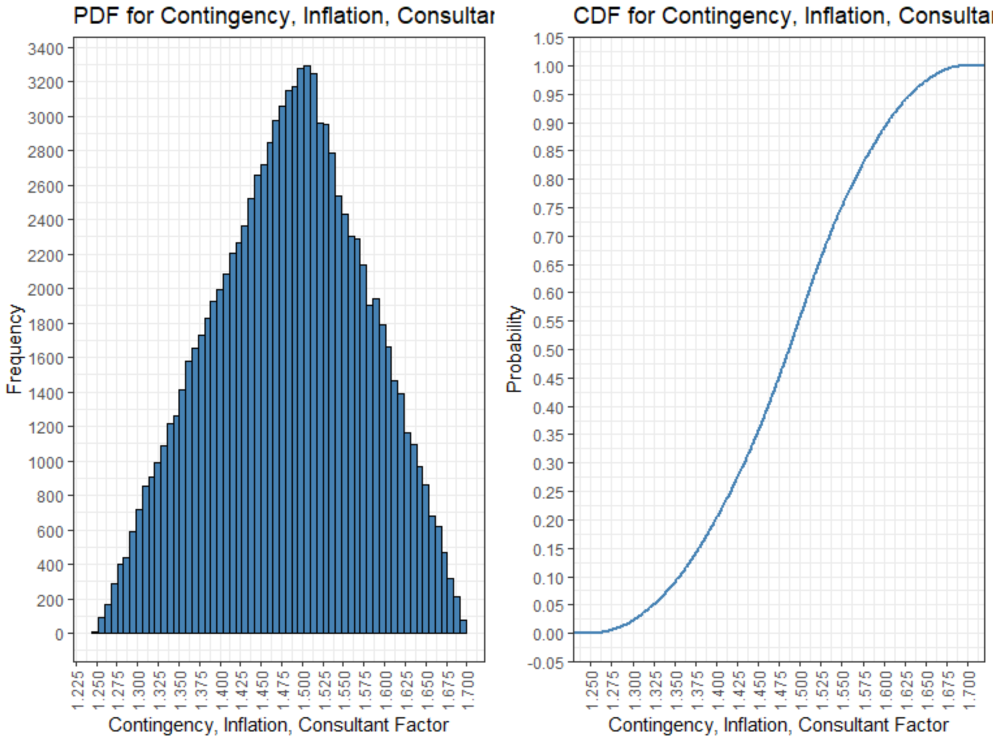

Exhibit B.9 Probability and Cumulative Density Functions for Contingency, Inflation, and Consultant Costs (Triangular Distribution)

Percentile (P)	Contingency, Inflation, Consultant Factor Percentile - Triangular
5	1.325065
10	1.356349
15	1.379454
20	1.399706
25	1.417625
30	1.433977
35	1.448575
40	1.462307
45	1.474998
50	1.487167

Exhibit B.10 Contingency, Inflation, and Consultant Costs by Percentile (Triangular Distribution)

The total cost using the triangular distribution approach can be obtained using the following formula:

Total ROW cost = selected acquisition cost percentile + (selected acquisition cost percentile × selected condemnation percentage percentile) + (selected relocation cost percentile) + selected asbestos abatement and demo cost percentile + [(1 - selected contingency percentile factor) × selected acquisition cost percentile]

Examples of Generating Total ROW Cost Based on Triangular Distribution

Example 1: Use P30 to obtain the total cost.

The total ROW cost is estimated using the approach found in Exhibit 45. In this example, P30 is used for each item. P30 is the value under which the estimator is 30% confident that the final value will fall and is willing to accept the 70% likelihood that the value will be more than the P30 value. The P30 values for the items are listed in Exhibit B.11.

Cost Item	P30 Value
Estimated Acquisition	7060912
Condemnation Percentage	0.3775361
Relocation	503159.9
Asbestos, Abatement, Demo	160311.2
Contingency, Inflation, and Consultant	1.433977

Exhibit B.11 P30 Values for Simulated Cost Items Using Triangular Distribution

By utilizing the percentiles table, the total ROW cost = (7060912) + (0.3775361 × 7060912) + 503159.9 + 160311.2 + [(1.433977 - 1) × (7060912)] = $ 13,454,406.

2.7.2 Example 2: Use P80 to obtain the total cost.

Similar to Example 1, P80 values were obtained from the percentile table and used in the total ROW formula. In this case, the estimator is willing to accept 20% of the risk of overrun by the P80 values under which the values of the items are 80% likely to fall. The P80 values are presented in Exhibit B.12.

Cost Item	P80 Value
Estimated Acquisition	7297678
Condemnation Percentage	0.4367288
Relocation	537703.2
Asbestos, Abatement, Demo	179463.8
Contingency, Inflation, and Consultant	1.566265

Exhibit B.12 P80 Values for Simulated Cost Items Using Triangular Distribution

Total ROW cost = (7297678) + (0.4367288× 7297678) + 537703.2+ 179463.8 + [(1.566265- 1) × (7297678)] = $ 15,334,371.

Example 3: Use P60 for all cost items and P30 for condemnation percentage.

The estimator can select the percentiles for which they are willing to accept the risk. In this example, the estimator is assumed to be confident in the estimates and believes that potential conflicts with land owners are unlikely. Thus, the estimator selects a low percentile (P30) for the condemnation percentage and P60 for the remaining cost items. The values are listed in Exhibit B.13.

Cost Item	P	Percentile Value
Estimated Acquisition	60	7194543
Condemnation Percentage	30	0.3775361
Relocation	60	522651.8
Asbestos, Abatement, Demo	60	171053
Contingency, Inflation, and Consultant	60	1.510479

Exhibit B.13 Percentile Values for Simulated Cost Items Using Triangular Distribution

Total ROW cost = (7194543) + (0.3775361× 7194543) + 522651.8+ 171053.0+ [(1.510479- 1) × (7194543)] = $ 14,277,111.

Probabilistic Estimate Cost Estimation Approach: Normal Distribution

In this section, the probabilistic cost estimate is carried out by utilizing normal distribution instead of the triangular distribution described in the previous section. In order to generate the normal distributions, the mean and standard deviations are estimated from the three-point estimates.

Major Cost Item 1: Estimated acquisition cost distribution

Exhibit B.14 shows the PDF and CDF distributions for the estimated acquisition cost. Exhibit B.15 shows a table of estimated values by percentile.

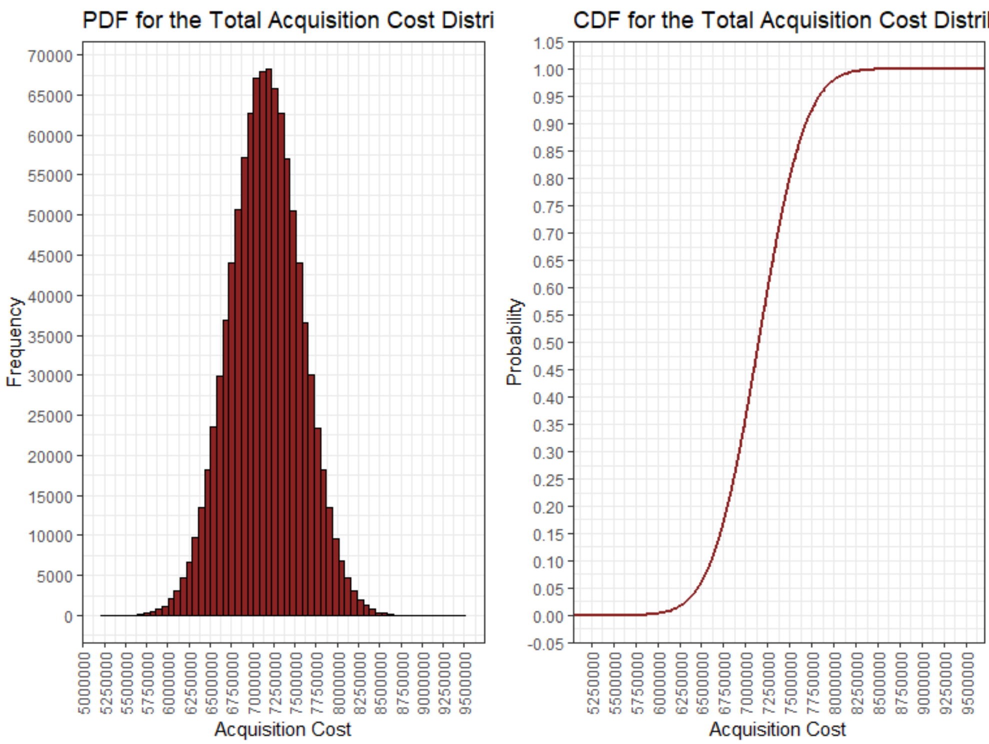

Exhibit B.14 Probability and Cumulative Density Functions for Acquisition Cost (Normal Distribution)

Percentile (P)	Acquisition Cost Percentile – Normal
5	6464709
10	6616808
15	6719346
20	6800657
25	6870797
30	6933643
35	6991572
40	7046105
45	7099242
50	7152070

Exhibit B.15 Acquisition Costs by Percentile (Normal Distribution)

Major Cost Item 2: Condemnation cost percentage distribution

Exhibit B.16 shows the PDF and CDF distributions for condemnation cost. Exhibit B.17 shows a table of estimated values by percentile.

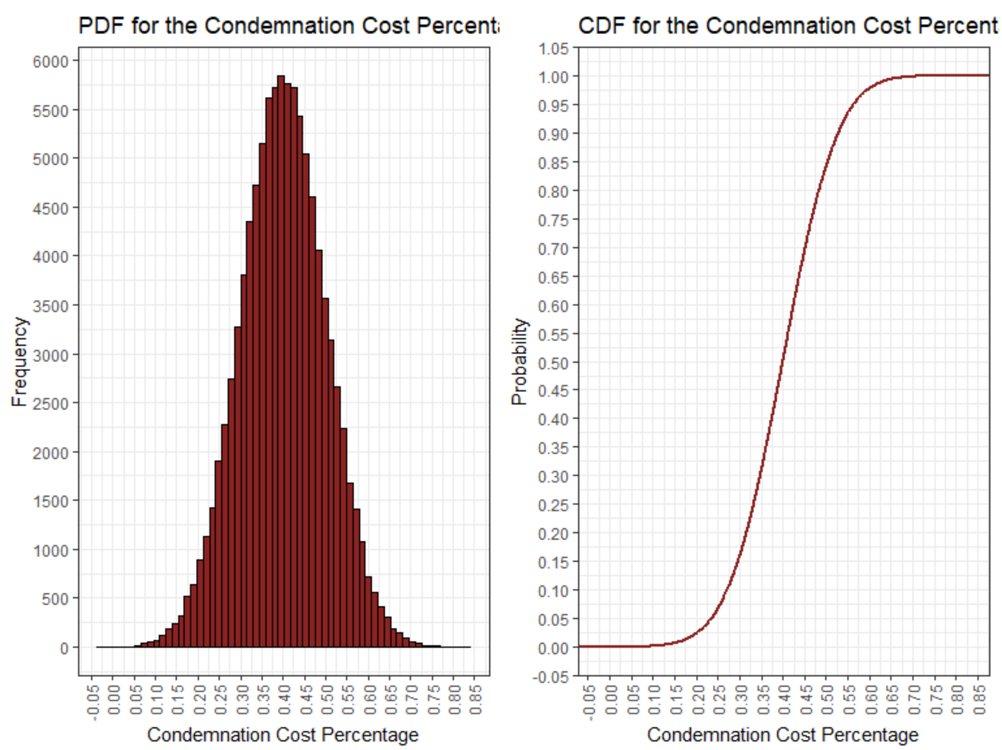

Exhibit B.16 Probability and Cumulative Density Functions for Condemnation Cost (Normal Distribution)

Percentile (P)	Condemnation Percentage Percentile - Normal
5	0.2352206
10	0.2718727
15	0.2967888
20	0.3160301
25	0.3327098
30	0.3477015
35	0.361767
40	0.3746192
45	0.3874214
50	0.4000546

Exhibit B.17 Condemnation Costs by Percentile (Normal Distribution)

Major Cost Item 3: Estimated utility relocation cost distribution

Exhibit B.18 shows the PDF and CDF distributions for the utility relocation cost. Exhibit B.19 shows a table of estimated values by percentile.

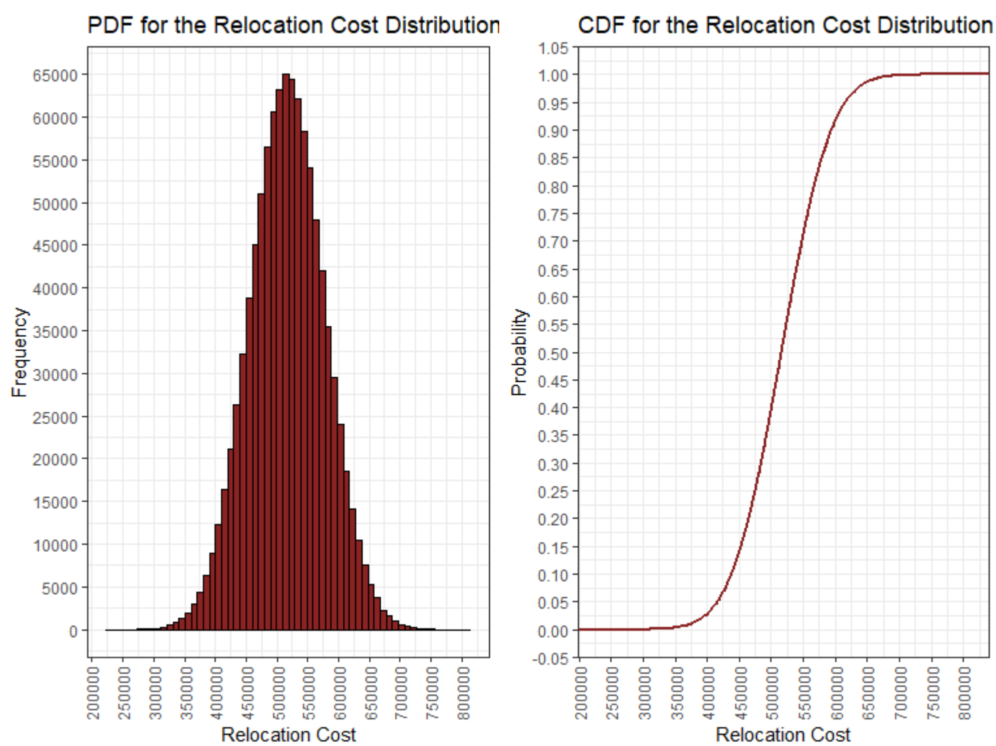

Exhibit B.18 Probability and Cumulative Density Functions for Utility Relocation Cost (Normal Distribution)

Percentile (P)	Relocation Cost Percentile - Normal
5	416575.5
10	438626.2
15	453621.9
20	465368
25	475605.7
30	484741.2
35	493203.2
40	501223.6
45	509008.1
50	516629.3

Exhibit B.19 Utility Relocation Costs by Percentile (Normal Distribution)

Major Cost Item 4: Asbestos abatement and demolition cost distribution

Exhibit B.20 shows the PDF and CDF distributions for asbestos abatement and demolition costs. Exhibit B.21 shows a table of estimated values by percentile.

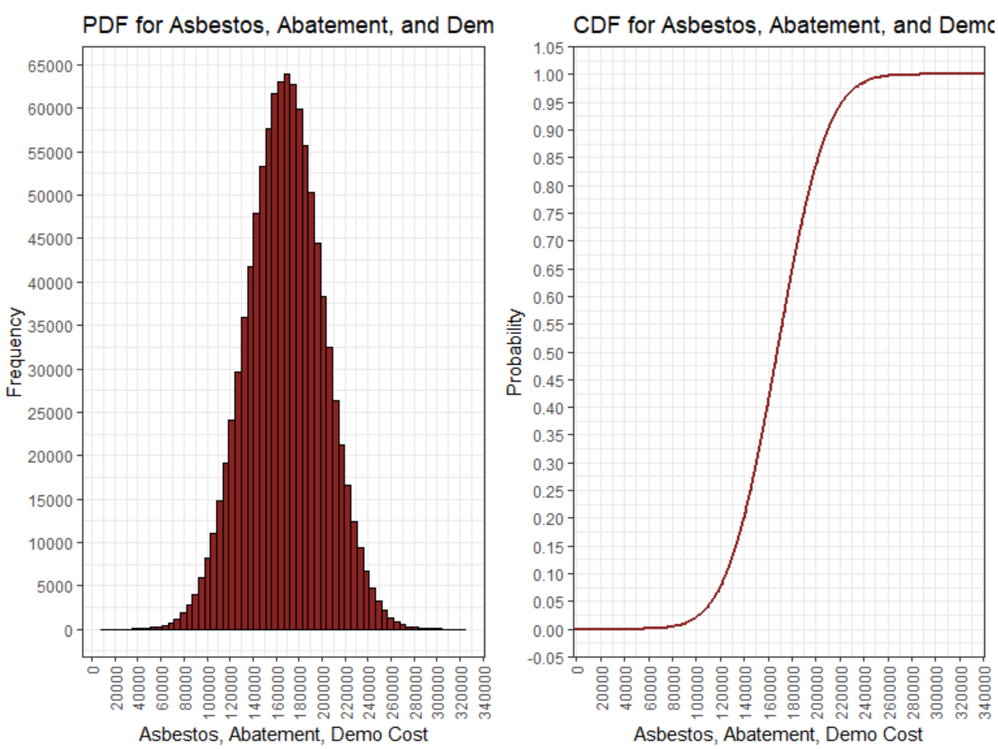

Exhibit B.20 Probability and Cumulative Density Functions for Asbestos Abatement and Demolition Cost (Normal Distribution)

Percentile (P)	Asbestos, Abatement, and Demo Percentile - Normal
5	113391.4
10	125488.4
15	133629.8
20	140099.2
25	145639.1
30	150621.8
35	155245.7
40	159598.2
45	163826.6
50	167988.1

Exhibit B.21 Asbestos Abatement and Demolition Costs by Percentile (Normal Distribution)

Major Cost Item 5: Contingency, inflation, and consultant costs

For the contingency allowance, generate the normal distribution from the following factors: 1.25, 1.5, and 1.7 (optimistic, most likely, and pessimistic estimates, respectively). 1.25 and 1.7 were selected subjectively, whereas the 1.5 × acquisition cost is the current NCDOT practice. Select the percentile, e.g., P85, and multiply it by the selected acquisition cost. Exhibit B.22 shows the PDF and CDF distributions for contingency, inflation, and consultant costs. Exhibit B.23 shows a table of estimated values by percentile.

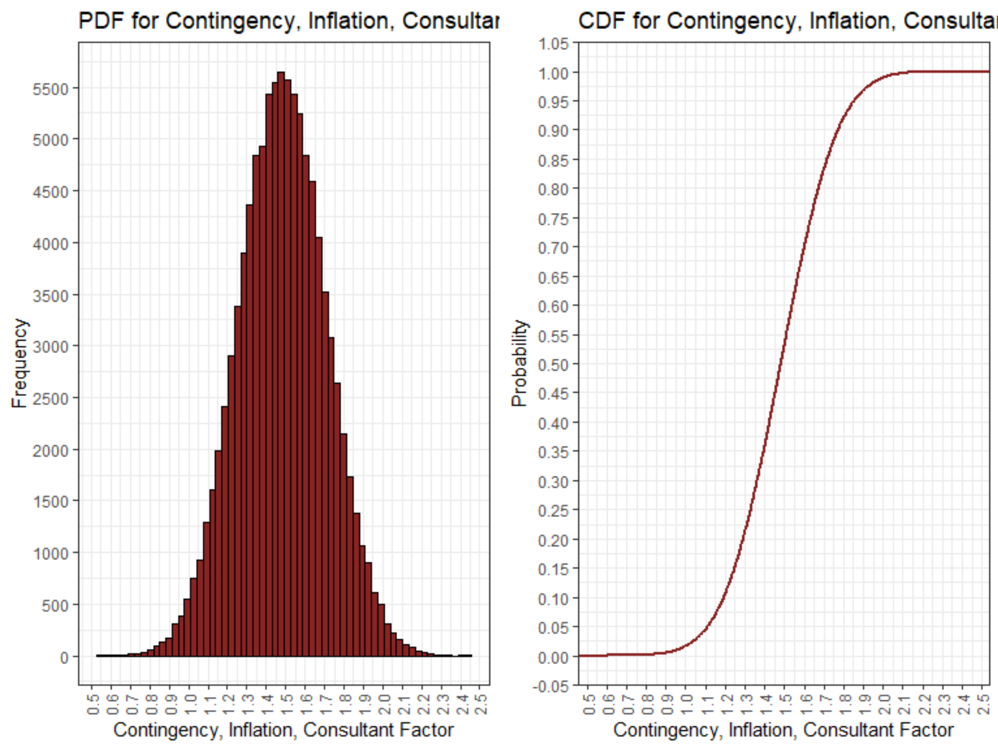

Exhibit B.22 Probability and Cumulative Density Functions for Contingency, Inflation, and Consultant Costs (Normal Distribution)

Percentile (P)	Contingency, Inflation, Consultant Factor Percentile - Normal
5	1.112789
10	1.194284
15	1.248956
20	1.292988
25	1.330267
30	1.363247
35	1.395902
40	1.425413
45	1.454364
50	1.482923

Exhibit B.23 Contingency, Inflation, and Consultant Costs by Percentile (Normal Distribution)

The total ROW cost using the normal distribution approach can be obtained using the following formula:

Total ROW cost = selected acquisition cost percentile + (selected acquisition cost percentile × selected condemnation percentage percentile) + (selected relocation cost percentile) + selected asbestos, abatement, demo cost percentile + [(1 - selected contingency percentile factor) × selected acquisition cost percentile]

Examples of Generating the Total ROW Cost Based on Normal Distribution

Example 1: Use P30 to obtain the total cost.

For Example 1, the total ROW cost is obtained using P30 for each item. P30 is the value under which the estimator is 30% confident that the final value will fall and is willing to accept the 70% likelihood that the value will be more than the P30 value. The P30 values for the items are listed in Exhibit B.24.

Cost Item	P30 Value
Estimated Acquisition	6933643
Condemnation Percentage	0.3477015
Relocation	484741.2
Asbestos, Abatement, Demo	150621.8
Contingency, Inflation, and Consultant	1.363247

Exhibit B.24 P30 Values for Simulated Cost Items Using Normal Distribution

Total ROW cost = $ 12,498,469

Example 2: Use P80 to obtain the total cost.

In this example, the P80 values were obtained as shown in Exhibit B.25.

Cost Item	P80 Value
Estimated Acquisition	7504539
Condemnation Percentage	0.4841497
Relocation	567891.4
Asbestos, Abatement, Demo	195785.3
Contingency, Inflation, and Consultant	1.673155

Exhibit B.25 P80 Values for Simulated Cost Items Using Normal Distribution

Total ROW cost = $ 16,953,254

Example 3: Use P60 for all cost items and P30 for the condemnation percentage.

The estimator can select the percentiles for which they are willing to accept the risk. In this example, the estimator is assumed to be confident in the estimates and believes that potential conflicts with land owners are unlikely. Thus, the estimator selects the low percentile (P30) for the condemnation percentage and P60 for the remaining items. The values are listed in Exhibit B.26.

Cost Item	P	Percentile Value
Estimated Acquisition	60	7258536
Condemnation Percentage	30	0.3477015
Relocation	60	532014
Asbestos, Abatement, Demo	60	176355.5
Contingency, Inflation, and Consultant	60	1.540571

Exhibit B.26 Percentile Values for Simulated Cost Items Using Normal Distribution

Total ROW cost = $ 14,414,463

Comparison between Values Obtained Using the Triangular and Normal Distribution Approaches

Exhibit B.27 presents the results obtained using the two distribution approaches based on the provided examples and assumptions along with the current NCDOT deterministic estimate.

Approaches	Triangular	Normal	NDCOT Estimate (One Estimate)
Example 1: P30	$13,454,406	$12,498,469	$13,177,901.00
Example 2: P80	$15,334,371	$16,953,254	
Example 3: P30 for condemnation and P60 for remaining items	$14,277,111	$14,414,463	

Exhibit B.27 Comparison between Triangular and Normal Distribution Approaches

Concluding Remarks

The probabilistic estimation approach relies on generating three-point estimates and then uses the three estimates to create a distribution (e.g., triangular or normal). In the examples provided in this appendix, the percentiles are obtained from the total. Another more detailed and sophisticated approach would be to select the percentile for each parcel individually based on a risk assessment exercise. For example, if Parcel A has more risks and uncertainties, then P85 would be selected. On the other hand, if Parcel B has minimum risks and its cost is unlikely to escalate, then P40 would be selected. Such an approach would make the estimation process challenging, however.

Ideally, a more useful and practical strategy would be to obtain the contingency factors from historical data and then create the distribution. Based on the contingency factor distribution, the estimator could then select the appropriate percentile. Furthermore, analysis could be applied at each project stage to obtain the suitable factor for each stage. One of the downsides of this approach is that it is computationally expensive if the estimator is estimating a project with many items as well as striving for precision by generating large Monte Carlo samples (in this report, 100,000 runs were performed). Whether or not commercial software would be able to handle the calculations without crashing remains unclear.

The NCDOT lacks clear definition regarding the cost items that the ROW contingency allowance should cover. A contingency allowance typically is added to cover known-unknowns. Creating lists of the known-unknowns for the ROW cost portion that a contingency cost item can cover would be a valuable practice for the NCDOT to follow.

Appendix C. Analysis of Time between Estimate Stages, Letting Date, and Acceptance Date

Appendix C presents an analysis of the time differences between each estimate compared to the project letting and acceptance data.

Exhibit C.1 reports the summary statistics for the analysis of the times between the estimate stages, letting date, and acceptance date in terms of number of days. For example, the number of days between Estimate 1 and Estimate 2 is 795 days on average.

From	To	N (days)	Mean	Lower 95% Mean	Upper 95% Mean	Median	Q25	Q75	SD	Standard Error
Estimate 1	Estimate 2	55	794.95	606.69	983.20	641.00	310.00	1107.00	696.38	93.90
Estimate 1	Estimate 3	93	981.23	812.21	1150.24	756.00	477.00	1265.00	820.67	85.10
Estimate 1	Estimate 4	112	1343.18	1173.53	1512.83	1100.50	825.75	1497.50	906.05	85.61
Estimate 1	Let	74	1452.66	1240.49	1664.84	1172.00	956.75	1685.50	915.81	106.46
Estimate 1	Acceptance	111	2034.37	1836.70	2232.04	1719.00	1379.00	2379.00	1050.89	99.75
Estimate 2	Estimate 3	97	703.87	541.06	866.67	415.00	219.50	897.00	807.79	82.02
Estimate 2	Estimate 4	121	1024.97	875.90	1174.04	757.00	553.00	1246.00	828.19	75.29
Estimate 2	Let	69	1070.57	862.40	1278.73	768.00	593.00	1213.00	866.55	104.32
Estimate 2	Acceptance	116	1968.68	1754.37	2183.00	1630.00	1115.75	2434.00	1165.31	108.20
Estimate 3	Estimate 4	176	439.77	393.08	486.46	383.50	329.25	476.00	313.85	23.66
Estimate 3	Let	103	464.45	400.77	528.13	407.00	365.00	483.00	325.83	32.11
Estimate 3	Acceptance	170	1355.39	1258.56	1452.22	1152.00	832.50	1810.00	639.53	49.05
Estimate 4	Let	111	28.74	25.85	31.63	27.00	20.00	36.00	15.37	1.46
Estimate 4	Acceptance	232	885.81	818.89	952.73	771.50	486.25	1118.50	517.32	33.96
Let	Acceptance	228	638.32	582.16	694.48	492.50	365.00	747.75	430.33	28.50

Exhibit C.1 Analysis Results for Times between Estimate Stages, Letting Date, and Acceptance Date

Appendix D. Uncertainty Quantifications for Reserve Allowances

For completeness, Appendix D provides the optimistic, most likely, and pessimistic Reserve Allowances for this study even though the study recommends using the most likely values.

For each recommended reserve allowance percentage, the uncertainty quantification for the reserve allowance for each project component (construction, right-of-way, and utility relocation) is based on the mean at the 95% confidence interval. The mean is considered to be the 'most likely' value. The lower limit of the confidence interval is assumed as the 'optimistic' reserve percentage, whereas the upper limit of the confidence interval is considered as the 'pessimistic' reserve percentage.

Stage	Bridge Projects Project Size: >$1M		
	Optimistic	Most Likely	Pessimistic
Stage I	20	35	45
Stage II	15	25	35
Stage III	5	15	20
Stage IV	0	0	2

Stage	Bridge Projects Project Size: ≤ $1M		
	Optimistic	Most Likely	Pessimistic
Stage I	0	0	5
Stage II	0	0	5
Stage III	0	0	0
Stage IV	0	0	0

Stage	All Projects Except Bridge Projects		
	Optimistic	Most Likely	Pessimistic
Stage I	5	30	55
Stage II	5	25	40
Stage III	0	20	45
Stage IV	0	5	10

Exhibit D.1 Uncertainty Quantification for Construction Reserve Allowances

Stage	Bridge Projects		
	Optimistic	Most Likely	Pessimistic
Stage I	60	85	110

Stage	All Projects Except Bridge Projects		
	Optimistic	Most Likely	Pessimistic
Stage I	0	60	140

Exhibit D.2 Uncertainty Quantification for Right-of-Way Reserve Allowances

Stage	Bridge Projects		
	Optimistic	Most Likely	Pessimistic
Stage I	0	0	20

Stage	All Project Except Bridge Projects		
	Optimistic	Most Likely	Pessimistic
Stage I	0	65	190

Exhibit D.3 Uncertainty Quantification for Construction Utility Relocation Reserve Allowances