Independent Cost Estimates for Design and Construction of Transit Facilities in Rural and Small Urban Areas

DETAILS

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AUTHORS

ICF International, Inc.

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Responsible Senior Program Officer:
Gwen Chisholm Smith

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INDEPENDENT COST ESTIMATES FOR DESIGN AND CONSTRUCTION OF TRANSIT FACILITIES IN RURAL AND SMALL URBAN AREAS

This digest presents the results of NCHRP Project 20-65, Task 53, “Independent Cost Estimates for Design and Construction of Rural and Small Urban Transit Facilities.” The research was conducted by ICF International, Fairfax, Virginia, in association with Stuart Anderson, Texas A&M University, principal investigator, and Keith Molenaar, University of Colorado, and Clifford Schexnayder, Arizona State University, co-principal investigators.

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SUMMARY

Most organizations that develop and deliver capital projects have a continuing program of projects. While large projects tend to have more visibility in these programs, small projects, when combined, often result in a substantial percentage of the total construction budget within a program. Overruns in many small projects can lead to program overruns and hence be just as problematic as overruns on a few large projects.

Estimating design and construction costs in a consistent, reliable, and accurate way is critical for an organization since the information generated is the basis for projecting program funds, prioritizing projects by financial analysis, determining required funds, and providing a baseline for project control. This research focused on cost estimating methods and database development for design and construction of rural and small urban area transit facilities, which are usually small, numerous, and geographically dispersed.

In order to address these problems, NCHRP funded the research to provide guidance to state transit agencies in assisting their sub-recipients with preparing accurate design and construction cost estimates. The products of the study include a cost estimating database and an estimating prototype tool for rural and small urban area transit facilities. The prototype tool is available on the TRB website (www.trb.org) by searching for “NCHRP Research Results Digest 397.” The cost estimating database and prototype tool can support conceptual estimating in the planning phase. This document is independent of the cost estimating database and prototype tool. Please refer to the introduction and user’s guide in the prototype tool for more information before using the tool.

The objectives of this study were to determine the distinct characteristics of rural and small urban area transit facilities, collect actual historical cost data, and develop a cost estimating database and prototype tool to assist agencies with preparing conceptual estimates. The limitations of this research and recommendations for future research are described at the end of this digest.

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CHAPTER 1 INTRODUCTION

Background

Rural and small urban area transit facility projects are relatively small in scope and dollar value, numerous, and geographically dispersed in small communities. It is difficult to estimate the design and construction costs for such projects because of:

- Variations in functions and project size,
- Different amenities associated with the facilities,
- Possible renovation of existing facilities,
- Lack of historical cost data,
- Unique risk factors affecting cost (e.g., remote location or lack of competition), and
- Absence of structured estimating processes.

Extensive research has been performed and provides many technical and managerial references for estimating the cost of large urban construction projects. Selected research provides both a strategic focus and a how-to focus. *NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction* (Anderson et al. 2007) is a guidebook that identifies internal and external cost escalation factors and recommends appropriate global estimation strategies. Applications of methods for relevant strategies and tools to implement methods are also provided for each phase of project development: planning, programming and preliminary design, final design, and implementation. The guidebook also describes the cost estimating and cost management processes in terms of nine general steps. The Minnesota Department of Transportation *Cost Estimation and Cost Management: Technical Reference Manual* (Minnesota Department of Transportation 2008) describes the estimating procedures in detail.

Recent research specific to rural projects includes *NCHRP Research Results Digest 381: Guidebook for Construction Management Practices for Rural Projects* (Hallowell et al. 2012). The digest addresses issues such as construction administration, engineering, operation, and safety; cost estimation; scheduling; quality control and assurance; and claims and disputes based on proven management strategies. It does not cover cost estimating processes and methodologies for rural transit projects.

There is a lack of compiled cost information or databases to support cost estimation of rural and small urban area transit facilities. Many factors cause this situation. First, few research projects have been conducted on collection of cost data for these types of facilities. Second, the functions and scopes of these facilities vary. For example, some facilities in rural and small urban areas serve as operations and maintenance buildings, while some are constructed in order to facilitate passengers, but these can be combined with operations facilities. The garage space can be relatively larger if the fleet size is large. Depending on the number of passengers served, the passenger facilities may vary from unsheltered bus stops to transit terminals to transit centers. Third, the project can involve new facilities, but correspondingly the project may involve renovation and improvement works. Last, rural transit projects can receive funding from different sources and be administered by different agencies that may require that funding receivers follow different cost management procedures. Section 5311, the FTA's formula assistance program for rural providers, is administered by the state departments of transportation (DOTs), while tribal transit providers receive funding from grant programs directly, including Section 5307, urbanized area funds; Section 5309, bus and bus facilities discretionary program funds; and Section 5311 (c), tribal transit program funds. These funding programs are directly administered and managed by the FTA.

Without a good cost estimating database of rural and small urban area transit facility project costs, it is difficult to prepare consistent, reliable, and accurate cost estimates. Therefore, there is a need to study the unique characteristics of rural and small urban area transit facility projects, establish a sound and structured historical cost estimating database for design and construction, and develop a corresponding tool to facilitate the estimating process. The scope of this digest covers these three issues.

Problem Statement

The FTA requires all state agencies receiving federal funding for the design and construction of rural and small urban area transit facilities submit independent cost estimates from their sub-recipients for both design and construction as part of the application and grant implementation process.

There appears to be no local or national standard methodology or criteria for developing independent cost estimates associated with the design or construction of these types of transit facilities at the application stage. The objective of this research is to produce guidance for use by state transit agencies in assisting their sub-recipients with preparing and reviewing accurate design and construction cost estimates.

Research Questions

The research questions of the project are discussed in the following.

- Characteristics and classification of rural and small urban area transit facilities
  - Based on functional types, how are the rural and small urban area transit facilities classified? What are the prevalent functional types?
  - How do locations of rural and small urban area projects affect the design and construction of these facilities? What are the differences between rural and small urban area transit facilities?
  - For each functional type, what is the typical project size in square feet (sf), as either an average or a range? What is the typical project cost, as either an average or a range?
- Cost estimating database and tool
  - What historical cost data does a state agency capture from bids or construction to support estimation of design and construction costs of future projects? If cost data are captured, does the agency have a database of these costs available? Where does the database reside, field offices or a central location?
  - What are the practical cost estimating methods and tools that have a history of success within the transit facility industry, such as scoping documents and summarized estimating steps?
  - How is the historical cost estimating database developed in this research used to support estimating design and construction costs of rural and small urban area transit facilities?
- Risk assessment
  - What are the typical risks for these projects, considering functional type?
  - How can these risks be accounted in the project cost estimates and schedule?

Research Objectives

The main research objectives were to define the characteristics of rural and small urban area transit facilities, develop an appropriate cost estimating database of relevant historical cost elements, and create a prototype tool to support a conceptual estimating process for these facilities. This research had the following three sub-objectives:

- Identify the current estimating practice in the transit facility industry.
- Study the characteristics of available databases and create regression models for predicting project design and construction costs.
- Incorporate the cost estimating prototype tool to facilitate cost estimation.

Research Tasks

In order to achieve the objectives stated previously, this research included the following five tasks:

Task 1: Conduct a Review of Recently Designed and Constructed Rural and Small Urban Area Transit Facilities Throughout the United States

The objective of Task 1 was to determine the characteristics of rural and small urban area transit facilities and to understand the extent of the state of practice. A literature review and telephone interviews were conducted to collect key information related to typical types and sizes of facilities, location characteristics, and the availability of historical cost data for design and construction. The interview results confirmed or made corrections for findings from the literature review.

Task 2: Scan of Rural and Small Urban Area Transit Facilities

The objective of Task 2 was to collect data and information concerning rural transit facilities to identify, at a minimum, (1) size and type of facility designed and constructed, (2) amenities provided, (3) location of facility, (4) any unusual conditions, and (5) actual costs of design and construction. An online survey was used to collect this information on a project level.

Task 3: Develop a Database of Actual Costs

The objective of Task 3 was to develop a database of design and construction costs of rural and small urban area transit facilities. The historical cost data collected were input into an MS Excel database and normalized to the national average in year 2014 by using the city cost index and historical cost index in the 2014 version of the *RS Means Building Construction Cost Data* manual.

Task 4: Develop a Cost Estimating Methodology to Support Conceptual Estimating

The objective of Task 4 was to develop a cost estimating prototype tool using Excel based on statistical analysis of the cost estimating database developed in the previous task. A regression analysis was conducted to determine the relationship between cost and project size. Thus the regression function was built into the created prototype tool to predict project cost. The research background, instructions, and estimate report and details were also provided in this tool.

Task 5: Develop Cost Estimating Reviewing Guidelines and Prepare a Research Report

The objective of Task 5 was to develop guidelines to support a cost estimating reviewing process for rural and small urban area transit facilities and complete the research report following the NCHRP guidelines. The guidelines of the cost estimating reviewing process are provided in Chapter 7.

Organization of the Study

This digest contains eight chapters. Chapter 1 sets the context of the research background along with the problem statement, research questions, research objectives, and research tasks. Chapter 2 focuses on the literature review concerning characteristics of transit facility projects in rural and small urban areas, cost estimating databases and tools, and risk management practices. Chapter 3 describes the research methods, including the telephone interviews, online survey, survey data analysis, development of the cost estimating database and prototype tool, and review of the prototype tool. Chapter 4 provides information on the telephone interview protocol preparation, interview processes, and interview results. Chapter 5 discusses the survey protocol's development, the survey process, and the results of the data analysis. Chapter 6 presents the development of the cost estimating database, prototype tool, and estimating steps for rural and small urban area transit facilities. Limitations of the prototype tool are also addressed at the end of the chapter. Chapter 7 provides guidelines of reviewing cost estimates for rural and small urban area transit facility projects. Finally, Chapter 8 states study conclusions and discusses the recommendations for future research.

CHAPTER 2 LITERATURE REVIEW

A literature review was conducted to acquire knowledge about the types of transit facilities in rural and small urban areas and to determine current cost estimating practices of the agencies responsible for these facilities. The literature review was necessary to support the design of interview and survey protocols and to provide insights into the development of the cost estimating prototype tool. Searches were conducted for definitions of rural and small urban areas, transit facility functions and characteristics, cost estimating methodologies, and risk identification tools and measurement methods.

The following databases were surveyed as part of the literature review:

- The Transportation Research Board's Transportation Research Information Services (TRIS).
- Academic engineering databases, such as Engineering Village 2.
- Academic business databases, such as EBSCO Business Source Complete and Management and Organizational Studies.
- ASCE Civil Engineering database.
- General Internet search engine–Google Scholar.
- Selected transportation agency websites.
- The Metropolitan Transportation Commission's online library.

Review of the Transit Facility Industry in Rural and Small Urban Areas

According to the definition given by the FTA, a rural area is defined in two ways by the U.S. Department of Transportation (Dye Management Group 2001). The first definition is an area with fewer than 5,000 people. The second definition is that rural is an area outside of a metropolitan area and having a population of fewer than 50,000 people. Researchers interested in the transit facility industry can choose either definition according to their research needs. Hallowell et al. (2012) considered rural as an area with a population of fewer than 50,000 people. Their research identified cost estimating challenges, including the lack of historical data, remote locations, and less competition. To overcome these challenges, the researchers suggested many strategies and resources, such as state agency cost catalogues and detailed cycle-time spreadsheets for equipment, material, and labor. In addition, contractors are a resource for gathering historical data and bid histories. Although Hallowell et al. pointed to examples of transit facilities that could include bus stations, administrative buildings, and storage facilities, there were no classifications according to facilities' functions.

According to the Texas Rural Transportation Plan (Texas Department of Transportation 2012), transit facilities are categorized into the following groups:

1. Operations and maintenance
   - Administration
   - General purpose
   - Maintenance
   - Vehicle storage
2. Large passenger facilities
   - Park and ride
   - Terminal or garage
   - Transit center
3. Small passenger facilities
   - Sheltered bus stop
   - Unsheltered bus stop
   - Sign-only bus stop

Both new and renovated facilities are considered in the capital investment of rural transit projects. The cost of renovating a facility is 75% of that for building a new facility of the same type. For the bus stops listed, Texas A&M Transportation Institute developed a cost per bus stop. For other types of facilities, the estimated cost per square foot is based on the Texas Department of Transportation Public Transportation Division's database of historical capital cost per square foot.

The recommended practice *Architectural and Engineering Design for a Transit Operating and Maintenance Facility* (American Public Transportation Association 2010) includes the steps necessary to implement a new bus transit facility project, basic scope information required as part of a request for proposal procurement, and an example of a scope of services procurement document. In this recommended practice, facility types are classified as:

- **Level I:** A primary service facility providing running maintenance and storage; activities performed in the facilities include fueling, washing, fare collection, light-bulb replacement, and fuel-level checks.
- **Level II:** A secondary maintenance facility is often called an inspection garage. Activities conducted in this type of facility include light maintenance, engine tune-ups, lubrications, inspections, tire changes, brake repair, minor body work, and activities performed in Level I.
- **Level III:** A third-level maintenance facility provides all kinds of vehicle maintenance, including engine and transmission rebuilding, testing, major body repairs, painting, and activities that can be conducted in Level I and Level II.

Intercity bus transportation also plays an important role in smaller communities and rural areas due to its accessibility and affordable price for the local residents (KFH Group, Inc. 2002). The intercity transit industry is a private for-profit industry that offers scheduled passenger service and a number of other services, including package express, charter, and tour services. Intermodal and multimodal terminals facilitate the coordination of the intercity bus services in both rural and urban areas (Fravel 2003). Regarding intercity transit facilities, the capital projects can be new intercity bus stations, intermodal facilities, administrative offices, and passenger amenities. The scope of facility projects can vary greatly, from low-cost repairs, ramps, or signs to major intermodal facilities in urban locations (Fravel and Barboza Jr. 2011).

The *Rural Transit Program Manual* [Ohio Department of Transportation (ODOT), Office of Transit 2012] was developed to assist rural transit services in complying with all applicable federal and ODOT requirements. The manual discusses the determination of the need for rural transit and the implementation, use, maintenance, and operation of rural transit facilities. A series of documents were prepared by ODOT to support a facility feasibility study, scoping process, acquisition, and construction process. The manual recommends four steps for facility construction, which are shown in Appendix A. The *Rural Transit Program Manual* also states that design costs are normally limited to 6% of the estimated construction cost.

Based on the evaluation of existing rural transit facilities in Ohio, a report concerning rural transit facility prototypes was developed by Brown & Bills

Architects. This report addressed guidelines for designing rural transit facilities from three aspects: general design guidelines, site guidelines, and building guidelines. Considering limited funding and lower operation and maintenance costs after construction, the building guidelines suggest that rural transit facilities should be constructed in a simple and elegant but economic manner (Brown & Bills Architects 2012). In order to build sustainable facilities, the report suggests that general design and site selection of rural transit facilities meet a Leadership in Energy and Environmental Design (LEED) rating of silver or higher.

Cost Estimating

According to the recommended practice of the Association for the Advancement of Cost Engineering International (AACEI), cost estimates for building construction can be categorized into five classes (Christensen 2011). The classes are determined by the level of project definition maturity, which is usually defined as a percentage of complete definition. The classification, maturity level, end usage of each class, methodology, and expected accuracy ranges are shown in Table 1.

As project definition levels evolve and more information becomes known, the expected estimate accuracy increases and accuracy range decreases. Besides project definition, there are systemic risks affecting estimate accuracy, such as project complexity, quality of reference cost estimating data, quality of assumptions used when preparing the estimate, and estimating techniques used.

Cost Estimating Databases

The *RS Means Building Construction Cost Data* manual is a primary and authoritative reference source of building cost information. RS Means tracks cost records from more than 900 cities in the United States and selected locations in Canada. A wide range of other key information is provided in the manual, including productivity rates, crew composition, and contractor overhead and profit rates. The manual facilitates estimation of either commercial and industrial projects or large multi-family housing projects from the planning stage to bid preparation.

For the purpose of preliminary and intermediate budget preparation and feasibility determinations, data in the square-foot cost section of the manual can be used. Project data from locations across the

Table 1 AACEI cost estimate classification.

Estimate Class	Maturity Level of Project Definition (expressed as % of complete definition)	End Usage (typical purpose of estimate)	Methodology (typical estimating method)	Expected Accuracy Range (typical variation in low and high ranges,[1] L–low range H–high range)
Class 5	0% to 2%	Functional area or concept screening	Square-foot (square-meter) factoring, parametric models, judgment, or analogy	L: −20% to −30% H: +30% to +50%
Class 4	1% to 15%	Schematic design or concept study	Parametric models, assembly-driven models	L: −10% to −20% H: +20% to +30%
Class 3	10% to 40%	Design development, budget authorization, feasibility	Semi-detailed unit costs with assembly-level line items	L: −5% to −15% H: +10% to +20%
Class 2	30% to 70%	Control or bid/tender, semi-detailed	Detailed unit cost with forced detailed take-off	L: −5% to −10% H: +5% to +15%
Class 1	50% to 100%	Check estimate or pre-bid/tender, change order	Detailed unit cost with detailed take-off	L: −3% to −5% H: +3% to +10%

NOTES: Adapted from the AACEI's Recommended Practice No. 56R-08: Cost Estimate Classification System, 2012. (1) The +/− value represents a typical percentage variation of actual cost from the cost estimate after application of a contingency for a given scope. The typical confidence level is a 50/50 chance of falling within the accuracy ranges.

United States are collected to develop the square-foot cost at the national average level, so the estimator's judgment and caution should be exercised when the square-foot data are used. If more precision is needed, the latest edition of the *RS Means Square Foot Costs* manual would be a better reference. However, the square-foot cost data in the manuals do not reflect characteristics of rural and small urban area transit facilities of small size and in remote locations.

When more design details are available, the cost data in the unit price section of the manual can be used to prepare the estimate. The unit price section gives average prices for thousands of items. The unit cost data are divided into the 50 divisions based on the Construction Specification Institute (CSI) MasterFormat system. In the reference section, additional information is provided about construction equipment rental costs, crew listings, historical cost indexes, city cost indexes, location factors, and a change order process.

City cost indexes and historical cost indexes are important references when comparing projects located in different areas and constructed at different times. According to RS Means, "a city cost index number is a percentage ratio of a specific city's cost to the national average cost of the same item at a stated time period" (RS Means 2014). Therefore, cost in one city can be adjusted to cost in another city and national average cost by using the following two equations:

$$\frac{\text{Index for City A}}{\text{Index for City B}} \times \text{Cost in City B} = \text{Cost in City A},$$

and

$$\frac{\text{Specific City Cost}}{\text{City Index Number}} \times 100 = \text{National Average Cost}.$$

Cost can be adjusted by using historical cost indexes and the following:

$$\frac{\text{Index for Year A}}{\text{Index for Year B}} \times \text{Cost in Year B} = \text{Cost in Year A}.$$

City cost indexes provide data for a number of cities in the United States and Canada. For those cities and locations that were not sampled, the manual suggests the cost index for a nearby city with similar economic characteristics be used. However, this suggestion lacks statistical validation. Migliaccio et al. (2013) compared different methods of estimating city indexes. First, they conducted a Moran's test within the Geographic Information System. The test showed significant auto-correlation between proximity and city cost index values in RS Means, which confirmed the method suggested by RS Means. Regarding methods to estimate cost indexes of cities not sampled by RS Means, the researchers compared the method suggested by RS Means with two alternative methods. One is called the "conditional nearest neighbor" (CNN) method and entails selecting the cost index of the nearest location listed in the city cost indexes within the same state as the location not included in the city cost indexes. This method considers the impacts of regulations and policies on construction costs. The other is called "state average" method and entails taking the average of city indexes within a state and using that average as a location adjustment factor for cities not sampled. For each city in the city cost index, assuming a city's index was not available, the researchers used those three methods to estimate the index. Conducting analysis on the difference between the estimates and actual cost indexes, the researchers found the estimate error of CNN had the smallest range and the lowest mean, median, standard deviation, and variance, which indicates the CNN method produces better estimates. The CNN method was used in this study.

Cost Estimating Tools

Early in the project life cycle, when there are many unknowns about a project's definition, parametric estimating models are usually used for the purpose of concept screening or schematic design. A parametric cost estimating model consists of one or more cost estimating relationships that are usually developed from regression analysis of historical cost data. The cost estimating relationships convert technical or project parameters into estimates. However, the accuracy and validity of these estimates are limited since the cost estimating relationships are built on many assumptions. The estimate results are often prepared following UniFormat II, which allows the design team to evaluate alternatives with ease (Manfredonia et al. 2010).

AACEI developed a parametric model for cost and value assessments (Association for the Advancement of Cost Engineering International 2014). This model supports estimation of building construction and design for offices, warehouses, industrial buildings, and labs that are steel or concrete structures with up to seven stories. The user needs to input parameters, such as floor area, floor height, number of floors, and percent of area as office. Then, once the "calculate" button is clicked, an approximate building cost estimate is shown in a browser window having two major sections. The costs include all labor, material, and contractor overhead and profits, excluding site improvements, furnishings, production equipment, and contingency.

DProfiler, developed by Beck Technology, integrates a conceptual three-dimensional model with the process of cost estimating during planning and conceptual design phases. This has been widely used by architectural, engineering, and construction firms (Khemlani 2008). DProfiler uses RS Means cost database information that can be updated quarterly in order to capture the most current cost data if the user pays a maintenance and support program fee. When a user starts a project in DProfiler, there are two important variables besides the project details. The first of these is the zip code for the project location, which is needed so the estimated cost can be adjusted to an appropriate local cost from the national average. The second is the building type. Using the building type, the application automatically enables corresponding cost data to be applied to the components of the model. The user can create, modify, and remove components based on the requirements of design. When estimating the cost of each component, the user can either use the default RS Means cost data or input adjusted unit costs. The calculation formulas can also be modified based on the user's specific needs. The estimates report can be generated in the format of CSI MasterFormat or UniFormat II. The model information can be exported into multiple formats, such as PDF, DPC, and XLS.

At later stages of design, a more precise estimate can be performed based on the actual quantities of the building components specified by the project drawings. A quantity take-off program is usually used at this stage. Programs such as On-Screen Takeoff, Paydirt, Constructware, and iSqFt, are commonly used in the construction industry. These programs translate and export dimension and quantity data directly from the project plans into an estimating system such as in Excel. Then, detailed calculations can be performed in the estimating system. The quantity take-off software enables the estimator to prepare an accurate estimate in an efficient way.

Risk Management

Many uncertainties are associated with project development. Project participants may fail to identify the uncertainties and make appropriate adjustments to an estimate, which gives rise to project cost overruns. In order to address this problem, *NCHRP Report 658: Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs* (Molenaar et al. 2010) discusses a series of systematic tools and management practices for use in risk identification, assessment/analysis, mitigation and planning, allocation, and monitoring and control. The guidebook explains risk priority ranking processes through risk analysis workshops. Once the prioritization of risks is completed, available resources for analysis, planning, and mitigation can be best allocated. One of the best tools to facilitate the risk ranking is a probability × impact matrix used for qualitative risk evaluation. Each risk factor's frequency and impact on project implementation are combined in a matrix. Combinations can be categorized as (1) high risk, (2) moderate risk, and (3) low risk. Risks are prioritized based on the results of matrixes, and therefore, the project team can assign resources to the risks having the highest potential adverse impact on the project. An example of a probability × impact matrix is shown in Figure 1.

Molenaar and Wilson (2009) developed a three-tier approach process to estimate contingency based on risk analysis for highway projects. Their three-tier process is shown in Figure 2.

Project complexity is categorized as (1) noncomplex projects, (2) moderately complex projects, or (3) most complex projects. Based on the determination of project complexity, one of three tiers of risk analysis and contingency estimating methods is selected. The three tiers are:

Type I—risk identification and percentage contingency: for noncomplex projects, a list of risks needs to be developed, and contingency is estimated as a percentage of project cost.

Type II—qualitative risk analysis and identified contingency items: for moderately complex projects, a probability × impact matrix analysis tool is recommended to rank project risks. Then, expected values of risks (the product of probability of occurrence of risks and cost impact on the project) with high ranking will complement the contingency calculated in the Type I analysis.

Level	Likelihood
A	Remote
B	Unlikely
C	Likely
D	Highly Likely
E	Near Certainty

ASSESSMENT GUIDE

Likelihood	a	b	c	d	e
E	M	M	H	H	H
D	L	M	M	H	H
C	L	L	M	M	H
B	L	L	L	M	M
A	L	L	L	L	M

Consequence

Level	Schedule	and/or	Cost
a	Minimal or no impact		Minimal or no impact
b	Additional resources required; able to meet		<5%
c	Minor slip in key milestones; not able to meet need date		5-7%
d	Major slip in key milestone or critical path impacted		7-10%
e	Can't achieve key team or major program milestone		>10%

RISK ASSESSMENT

High (Red)

Unacceptable. Major disruption likely. Different approach required. Priority management attention required

Moderate (Yellow)

Some disruption. Different approach may be required. Additional management attention may be needed

Low (Green)

Minimum impact. Minimum oversight needed to ensure risk remains low

Source: *NCHRP Report 658: Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs* (Molenaar et al. 2010).

Figure 1 Example of probability × impact matrix.

Type III—quantitative risk analysis and contingency management: for the most complex projects, a risk analysis workshop to identify project risks is conducted, and project cost and appropriate contingency are estimated by the workshop team members. It is important to keep project risk factors and estimated contingency updated across the project development process.

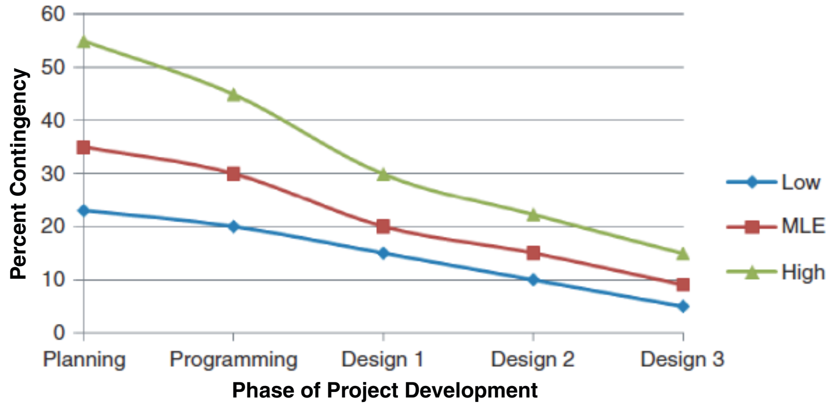
Baseline estimates and contingency are two major components of project estimates. Baseline estimates cover the development of estimated costs for all components of a project, exclusive of project contingency. This might be thought of as the bricks and mortar part of the estimate. Contingency is set to address project uncertainties and risks. The sum of the baseline estimate and the contingency provides the total estimate of project cost. As project definition becomes clear and information for cost elements becomes available, the baseline estimates increase while the contingency portion should decrease. Regarding the contingency estimating method, Olumide et al. (2010) used a Delphi study to collect a group of experts' opinions in contingency estimating for highway projects, and a top-down sliding-scale contingency estimating technique was developed. The method considers project complexity and the impact of different project development phases on project cost estimates. The method produces a range of contingency values. According to project complexity, project type is classified into three categories: most complex, moderately complex, and noncomplex. For each type of project, percent contingency decreases across the phases of project development with low, most likely, and high values provided for each phase. For example, for noncomplex projects, the sliding-scale contingency is shown in Figure 3.

Source: "A Risk-Based Approach to Contingency Estimation in Highway Project Development" (Molenaar and Wilson 2009).

Figure 2 The three-tier approach process to estimate project contingency.

AACEI's recommended general principles on contingency estimating include the following methods (Hollmann 2008):

Expert judgment—Contingency should be estimated based on the estimators' experience and



Source: "Sliding-Scale Contingency for Project Development Process" (Olumide et al. 2010).
Note: MLE = most likely estimate.

Figure 3 Sliding-scale contingency for noncomplex projects.

judgment on risk management and qualitative and quantitative analysis results.

Predetermined method—For each AACEI estimate class stated in Table 1, contingency should be estimated as a single value or a range.

Simulation analysis—The simulation analysis method determines project-specific risks and generates probabilistic output. Both expert judgment and the Monte Carlo simulation process are required. Monte Carlo simulation is computational probabilistic calculations that use random-number generators to draw samples from probability distributions (Anderson et al. 2007). In this case, Monte Carlo simulation is used to identify the effect of multiple uncertainties on the total project cost. One common method is called "range estimating." A range estimate represents a statement of project cost variability and conveys uncertainties in earlier stages of project development. First, a cost model that defines a total estimate at a certain level of detail should be determined. The model should consider all cost elements that have a significant impact on total cost estimates. Then, the project team assigns a range and distribution for each cost element and determines the correlations between cost elements. Finally, a Monte Carlo or similar simulation should be run based on ranges and distributions of the cost elements. The simulation results support the estimates by providing a total estimate's distribution and related data, such as mean, median, and standard deviation of the estimate.

Parametric modeling—A parametric model is generated from a multi-variable regression relationship that is found through analysis of quantified risk factors against cost escalation of historical projects. Once a risk factor is quantified by the project team, estimates, such as a most likely value and a range of costs, can be derived from the parametric model.

Since each method has both advantages and disadvantages, the report pointed out that the best approach is to use more than two methods to estimate cost of risk factors. Expert judgment is a fundamental estimating method and should be combined with any methods. Analysis results of a parametric model may provide reference on developing a predetermined estimating method.

Chapter Summary

Through the literature review, classifications of rural and small urban area transit facilities are defined. Project development processes, estimating practices, and prototypes of those facilities used by ODOT were reviewed. These resources provided insight for developing interview and survey protocols. Cost estimating techniques, databases, and cost estimating tools used in the construction industry were reviewed. Finally, risk analysis and contingency estimating were studied.

CHAPTER 3 RESEARCH METHODOLOGY

A clear research methodology ensured that the research objectives of this study were achieved in a systematic, logical, and effective way. The research methodology of this study included a literature review, telephone interviews, a survey, and survey data analysis. Based on the analysis, a cost estimating prototype tool was developed and tested.

Methodology

The logic of development of this research is shown in Figure 4. The problem identification and literature review discussed in the previous chapters were fundamental to the development of the telephone interviews, survey protocols, and estimating prototype tool.

Telephone Interviews

A telephone interview protocol was developed to better understand the characteristics of rural and small urban area transit facilities. Interviewees included personnel at state DOTs, transit managers, and consultants involved in design and construction of rural and small urban area transit facilities. Their contact information was obtained from the Rural Transit Assistance Program (RTAP). Before the interview, a research project memorandum and a list of questions were sent to the interviewees so that they could be prepared for the discussions.

Telephone Interview Summarization

The summarization of interview results reflects the typical characteristics of rural and small urban area transit facilities suggested by the interviewees. For example, the descriptions of risk factors were aggregated based on all interviewees' inputs. In addition, typical unit prices for different facility types provided by the interviewees were normalized to the 2014 national average. The results of the interviews assisted in the design of the survey questions.

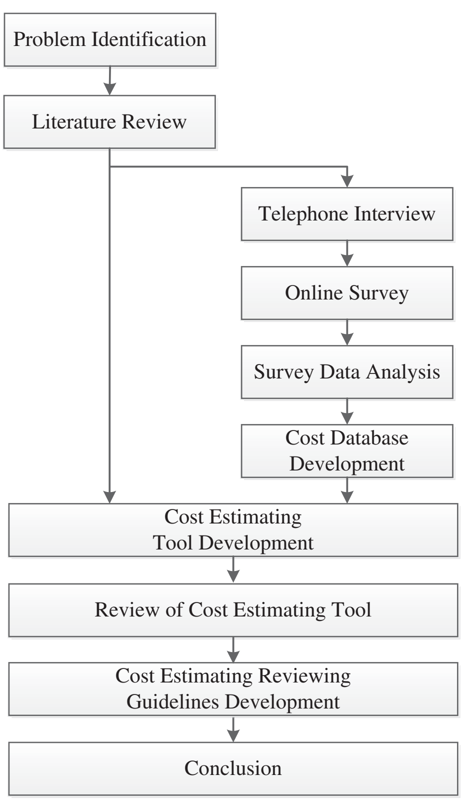


Figure 4 The research process.

Online Survey

Based on the literature review and telephone interview results, survey questions were developed to collect specific historical design and construction cost data from transit agencies. The survey provided the initial input to the cost estimating database and was designed to capture data from the following key information:

- Size and type of facilities,
- Different facilities features,
- Locations of facilities,
- Actual design costs,
- Actual construction costs,
- Design schedule (start and finish),
- Construction schedule (start and finish),
- Unusual conditions surrounding the projects, and
- Major facilities' component costs of construction.

The pilot survey protocols were sent in PDF format to three transit managers, two DOT personnel, and two consultants. The feedback from this pre-test was important for revising the survey. After the survey protocol was finalized, the online survey was developed via the Texas A&M Transportation Institute's online survey tool. Potential participants included state DOT Section 5311 program managers, transit managers, and consultants. Email addresses were provided by RTAP. With the help of personnel from RTAP, survey invitations explaining the background and objectives of the research as well as the online survey link were sent to potential survey participants. Several methods were used to improve the survey response rate, including sending follow-up emails, shortening the length of the survey, and phone calls to transit managers. Emails asking for clarifications concerning survey results were also sent to participants.

Survey Data Analysis

With the help of the online survey software, all survey results were exported to Excel, where data were normalized to the 2014 national average before further data analysis. The *RS Means Building Construction Cost Data* manual has a city cost index that includes many cities in all the states. The index of each city represents a percentage ratio of a building component's cost at any stated time to the national average of that same component at the same time. The cost index of the national average is 100. A national average cost can be calculated with the equation:

$$\frac{\text{Specific city cost}}{\text{City index number}} \times 100.$$

For cities that are not listed in the city cost index, the CNN method (the value of the nearest city included in the city cost index within the same state as the city not included in the city cost index) was used in this study as suggested by the research of Migliaccio et al. (2013). For example, a project was constructed in Fresno, California, in 2009 with an actual construction cost of $1,170,000. The city cost index is 107.9. Thus, the national average cost in 2009 of this project is $\frac{\$1,170,000}{107.9} \times 100 = \$1,084,337.$ The manual also has a historical cost index that can be used to convert national average building costs in a particular year to approximate building costs for some other time. The equation is:

$$\frac{\text{Index for Year A}}{\text{Index for Year B}} \times \text{Cost in Year B} = \text{Cost in Year A}.$$

For the project in the previous example, since the cost indexes of 2009 and 2014 are 180.1 and 202.7, respectively, the national average construction cost in 2014 is $\$1,084,337 \times \frac{202.7}{180.1} = \$1,220,406.$

In John's Macintosh Program (a statistical analysis system known as JMP), regression analysis was performed at a 90% confidence level (10% significance level) to determine the relationship between design cost and project size, and the relationship between construction cost and project size. In order to prove the necessity of a regression model, a hypothesis test should be conducted. The null hypothesis (H_0) was that no regression model was needed, and the alternative hypothesis (H_1) was that a straight-line regression model was required. Therefore, if the p-value of the test is less than the significance level (10%), then the null hypothesis should be rejected. That is, a regression model is needed.

In order to evaluate fit of the regression model, the value of R-square should be checked. R-square is calculated as a ratio of a model's sum of squares and total sum of squares. A large R-square value (close to 1.00) indicates a close fit of the data to the estimated line.

In the database, different combinations of administration, operations, maintenance facility, and vehicle storage were categorized. For each combination of facilities, the percentage of construction cost for each construction system was calculated by taking the average of the survey responses. For example, for projects that were combinations of four types of facilities (administration, operations, maintenance, and vehicle storage), seven people provided gross percentages for building site work. The average value of the percentages was taken. The results of average percentages provided a reference for estimating a percentage breakdown for each construction system in the cost estimating prototype tool.

Cost Estimating Database Development

The survey data for park-and-ride facilities, sheltered bus stops, unsheltered bus stops, and sign-only bus stops were incomplete or limited. Therefore, the historical cost data collected to develop this database cover only those facilities in administration, operations, maintenance, and vehicle storage. Generally speaking, administration, operations, maintenance facilities, and vehicle storage were combined in most of the projects included in the database.

In the cost estimating database, the classification of building elements is the same as in the standards of the UniFormat II. Acting as a checklist for the cost estimating process, the standardized classification can facilitate communications among project participants (e.g., transit operators, state DOT staff, and consultants). The database includes project location, project type, midpoint of design time, midpoint of construction time, design cost (estimated and actual), construction cost (estimated and actual), percentage of construction cost for each construction system, and contingency percentage.

Cost Estimating Prototype Tool Development

Two experts in the field of cost estimating were consulted and assisted in the development of the cost estimating prototype tool. The prototype tool was developed in Excel based on the surveyed cost data analysis results. Once the user inputs basic project information, such as project location, size, and the midpoint of design and construction year, the tool will provide the user with the estimated design and construction costs and contingency values. Based on the research of Olumide et al. (2010), contingency percentage is estimated with low, most likely, and high values. The ranges of contingency percentage of survey and interview results were used to estimate low, most likely, and high values of contingency percentages.

Review of the Cost Estimating Prototype Tool

A review of the cost estimating prototype tool was conducted. The cost estimating experts first reviewed and tested the prototype tool. Then, both an evaluation questionnaire and the cost estimating prototype tool were sent to people who participated in the telephone interviews or online survey. The results of the review helped to improve the clarity of the instruction and the friendliness of the operational setting.

Cost Estimating Reviewing Guidelines Development

The basis of the cost estimating review guidelines for rural and small urban area transit facilities was derived from previous cost estimating research. The guidelines cover cost estimating processes and a checklist of questions for each step of the cost estimating process. The review guidelines aim at ensuring that the process is performed in a systematic and consistent manner.

Chapter Summary

This chapter discussed the research process and research methods used in the study. Details concerning telephone interviews and online surveys are presented in Chapters 4 and 5. The process of developing the cost estimating database and prototype is discussed in Chapter 6. The cost estimating review guidelines are provided in Chapter 7.

CHAPTER 4 TELEPHONE INTERVIEWS

Interview Protocol

Telephone interviews were used to conduct a review of recently designed and constructed rural and small urban area transit facilities. A structured interview protocol was developed based on the findings obtained from the literature review. It included 13 questions covering seven aspects of rural and small urban area transit facilities:

- Differences between rural and small urban area transit facilities,
- Typical project size,
- Typical design and construction costs,
- Availability of historical cost databases,
- Availability of checklists of critical estimate items,
- Typical risk factors, and
- Contingency estimation.

The duration of each interview was about 1 hour.

Interview Process

Thirteen potential interviewees (five DOT personnel, two consultants, and six transit managers) were selected. These professionals were located in different regions in the United States. Sending out interview invitations via email was the first step in the interview process. Six people (three DOT personnel, two consultants, and one transit manager) expressed their willingness to participate in the interviews. The project memorandum and interview protocol were sent via email to these individuals several days prior to the scheduled interview. This enabled the participants to review the protocol and prepare for the interview questions. The memorandum included the research background, expectations, and instructions, and confirmed the date and time of the interview. The research background covered the purpose and products of this research. The expectations and instructions outlined the key information sought from the interview. The team sought to develop a clear understanding the characteristics of different types of rural and small urban area transit facilities. The estimated interview duration was provided to the interview participants at the end of the memorandum.

Interview Results

The interview results cover seven aspects, which are summarized in this section. Inputs from DOT personnel, transit managers, and consultants were aggregated to reflect the typical characteristics of rural and small urban area transit facilities.

Differences Between Rural and Small Urban Area Transit Facilities

In small urban areas, transit facilities, such as maintenance buildings and indoor garages, are usually larger due to high volume of passengers that use the agency's transit services. Further, land is usually difficult to acquire to construct a transit facility. Small facilities, such as passenger shelters, are mainly located in urban areas. Although FTA's funding is often split 80/20, where 80% goes to urban transit facility projects and 20% goes to rural projects, lack of funding for rural transit facilities is one of the major causes of project delays.

Typical Project Size

Various factors have an impact on the size of a transit facility project, including employee ratio, fleet size, types of maintenance work performed, fleet mileage, the availability of funding, location, and the project's complexity.

The size range of an administration office was found to be from 2,500 to 3,000 ft^2. The size of a bus shelter can vary from 50 to 150 ft^2. The typical range of operation and maintenance facilities is about 8,000 to 13,000 ft^2. The size range of a vehicle storage building is from 8,000 to 12,000 ft^2. The size of a transit complex (including administration, storage, and garage) can range from 12,000 to 20,000 ft^2.

Typical Design and Construction Costs

The cost of rural and small urban area transit facilities varies based on project location, the features of facilities, change orders, soil conditions, geological conditions, weather conditions, environmental mitigation requirements, the application of the LEED rating system, the involvement of expansion and transformation of existing buildings, and legislative rules (e.g., the Buy America Act).

Generally speaking, the total cost of a rural or small urban transit facility is between $2 and $4 million. The cost can range from $8 to $24 million if a project is located in a West Coast area. The cost range of a paratransit facility is $12 to $16 million. (Paratransit is an alternative mode of flexible passenger transportation that does not follow fixed routes or schedules.) Table 2 shows unit costs of different types of facilities. With more features added, the unit cost would be higher.

Table 2 Unit costs of transit facilities.

Facility Type	Unit Cost
Administration	\$150–\$200/ft^2
Maintenance	\$300/ft^2 (The cost depends on what kind of maintenance service is performed.)
Open bus storage	\$125–\$250/ft^2

Availability of Historical Cost Databases

Few state DOTs or transit agencies maintain their own historical cost databases. They tend to hire consulting firms to perform certain tasks on their behalf, such as preparing and reviewing estimates and checking change orders for projects. However, consulting firms have separate cost databases for building construction, mechanical work, electrical work, plumbing, landscaping, and equipment. Both the *RS Means Building Construction Cost Data* manual and their own cost databases are used by the cost engineers of the consultants. Cost analysis is also conducted by cost engineers to identify reasons for cost overruns or underruns.

Availability of Checklists of Critical Estimate Items

Cost engineers in consulting firms maintain checklists of critical estimate items updated to be as current as possible. Design engineers help estimators maintain and update cost data. ODOT has a guidance report to support the design and estimation process for rural and small urban area transit facilities. Although state DOTs do not have checklists of critical estimate items, they hire consulting firms to perform an independent estimating review and track reasons behind delays and cost overruns.

Typical Risk Factors

According to the interviewees, the typical risk factors associated with rural and small urban area transit facilities are:

- Higher transportation expenses: construction in remote areas increases transportation expenses and the need to pay travel time.
- Soil conditions: contaminated soil or unexpected soil conditions.

- Buy America Act compliance: materials made in the United States must be used.
- Weather conditions: extreme weather, such as icy winters, heavy rains, and hurricanes.
- Unexpected underground conditions: buried debris and unexpected utilities.
- Funding availability: construction of rural transit facilities is often delayed because of funding constraints.
- Increased scope: continuous incremental changes in project scope.
- Environmental risk: new information required for permits or changes of environmental regulations.
- Neighborhood complaints: major complaints concerning noise and dust control can cause a lengthy construction delay.
- Archaeological impact: if relics are found on the site, construction is often suspended until relics are protected or removed.
- Lack of competition: lack of competition (i.e., the number of bidders per project) will increase bid prices, which gives rise to higher project cost.

Contingency Estimation

Contingency is set according to project type, size, location, and project characteristics. However, sometimes the contingency is not sufficient to cover all the unknown factors, such as weather conditions, soil conditions, site location, or needed change orders. According to the interviewees from state DOTs, 10% to 15% of construction cost is often suggested as an appropriate contingency. Design firms usually work with contractors to set a feasible contingency (percentage of construction cost) for design and construction.

Interview Results Summary

The interview results reveal the following characteristics of rural and small urban area transit facilities:

- Project size and costs vary due to different facility types, location, and facility features.
- Project risks were identified, such as soil conditions, Buy America Act compliance, and unexpected underground conditions.
- In order to address project risks, contingency is estimated as a percentage of construction cost; however, risks are seldom tied directly to the amount of contingency.
- Lack of funding for rural facilities often gives rise to project delays.
- DOTs and transit agencies often lack expertise in estimating design and construction costs, and they therefore depend on estimates provided by consulting firms.

Chapter Summary

This chapter discussed the interview protocol development and interview process. Then, results of the interviews were summarized. The collected qualitative data obtained from telephone interviews were used for developing the survey protocol, which is discussed in the next chapter.

CHAPTER 5 ONLINE SURVEY

Survey Protocol

The main objective of the survey was to collect historical project-specific cost data from state DOTs, transit agencies, and consulting firms. The data were collected on rural and small urban area transit facilities. The cost data served the purpose of developing a cost estimating database and a tool to support estimates' preparation. The survey protocol included 11 main sections:

- Background,
- Survey instruction,
- Survey declaration,
- Respondent information,
- General project information,
- Characteristics of the project,
- Cost estimating,
- Schedule,
- Risk,
- Change orders, and
- Other.

The background section served as a memorandum to explain the research objectives, provide contact information of the research team, and give the deadline for completion of the online survey. The survey instruction section described certain types of transit facilities that were designed and constructed in the last 5 years. The survey declaration aimed at confirming that the participants had basic knowledge related to the cost estimating practices for rural and small urban area transit facility projects and voluntarily consented to participate in the survey. Participants' email addresses were requested in case further clarification was needed at the end of the survey declaration section. Table 3 describes the other survey sections.

Before sending the survey to practitioners, the survey protocol was pretested in October of 2013. Three transit managers and one DOT employee participated in the pilot survey. The feedback from the pilot survey revealed that the respondents had difficulties in locating actual historical cost data and completing the open-ended questions on cost estimating, scheduling, and risks. Some transit operators lacked cost estimating expertise, and they relied on the estimates provided by consulting firms. Therefore, the survey protocol was redesigned by changing the open-ended questions to multiple-choice questions. The multiple-choice questions were tailored from the results of the interviews and pilot surveys. For example, risk factors, such as unexpected underground conditions, soil conditions, and environmental issues, were mentioned by interviewees and then added as choices in a question asking for the reasons for cost overruns.

Survey invitations were sent on November 6, 2013, to 52 state DOT personnel who manage public transit facility funding programs and 323 transit managers and consultants across the United States. The contact information of these potential participants was provided by the RTAP. Follow-up survey requests were sent to the same group of people on November 26, 2013. Unfortunately, there were only nine surveys submitted by respondents, which was much fewer than expected. This probably resulted from a limited number of transit facilities having been constructed in rural and small urban areas in recent years, difficulty of respondents in accessing project data, respondents having limited time to complete the survey, and respondents lacking cost estimating knowledge. In order to further reduce the difficulty of completing the survey and improve the response rate, the survey structure was changed and the size of the survey was reduced. The descriptions of the main body of the shortened survey are shown in Table 4.

Table 3 Descriptions of survey sections.

Section	Description
Respondent information	The name and type of agency that constructed transit facilities
General project information	• Project location • Design schedule (start and finish) • Construction schedule (start and finish) • Funding source(s) • Project delivery method • Design and construction contract type
Characteristics of the project	• Type and size of facilities • Different facilities' features and elements
Cost estimating	• The type of historical cost database used to prepare the estimates • Actual/estimated design costs • Actual/estimated construction costs • The percentages of construction cost for major construction systems • Estimating methods for design and construction • Influential factors in the cost estimating process
Schedule	• Actual/estimated design schedule • Actual/estimated construction schedule • Reasons for delays
Risk	• Methods to estimate the construction contingency • Unusual conditions surrounding the projects
Change orders	The reasons for change orders and their financial impacts on the projects
Other	Lessons about the estimating process learned from this project

Table 4 Descriptions of the shortened survey.

Section	Description
Respondent information	The name and type of agency that constructed transit facilities
General project information	• Project location
	• Funding source(s)
	• Project delivery method
	• Design and construction contract type
Characteristics of the project	• Type and size of facilities
	• Different facilities' features and elements
Cost estimating	• The type of historical cost database used to prepare the estimates
	• Estimating methods for design and construction
	• Actual/estimated design costs
	• Actual/estimated construction costs
	• Reasons for cost overruns in the project
	• The percentages of construction cost for major construction systems
Schedule	• Actual design schedule
	• Actual construction schedule
Risk	• Major risk factors
	• Methods to estimate the construction contingency
Change orders	The reasons for change orders and their financial impacts on the projects
Other	The availability of the cost estimating database and willingness to share information

Survey Process

The survey process is shown in Figure 5.

When the second-round survey was distributed, telephone calls were made to 25 transit managers across the United States to encourage them to participate. In order to collect more cost data, the invitations of the shortened survey were distributed to 1,055 transit managers and consultants, excluding the 323 people contacted during the first-round survey. The contact information of the 1,055 people was again provided by RTAP from its database. Follow-up invitation emails for the shortened survey were sent on February 7, 2014. Unfortunately, there were only 13 responses to the shortened survey by the end of February. Therefore, there were 26 surveys submitted by respondents, including four pilot surveys. Clarification requests were sent through emails if the respondents did not provide actual design and construction costs and design and construction schedules (start and finish data). Only one transit manager replied and provided a design and construction schedule for a project.

Survey Data Analysis

Table 5 shows original design and construction cost data collected through the online survey for 26 projects. Different types of facilities are combined in most of the projects. Only one project includes just one type of facility (operations). Eleven of the 26 projects consist of two or three types of facilities (e.g., administration and operations, or administration, operations, and vehicle storage). One project was a renovation project. Nine projects include four types of facilities (administration, operations, maintenance, and vehicle storage). Two projects concern small facilities for passengers

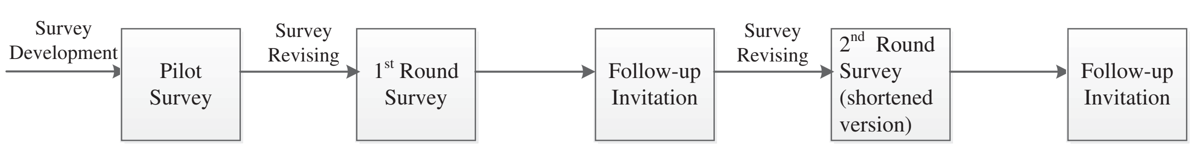


Figure 5 Survey process.

Table 5 Survey design and construction cost data.

#	Midpoint of Design	Midpoint of Construction	Facility Type	Project Size (sf)	Estimated Design Cost ($)	Actual Design Cost ($)	Estimated Construction Cost ($)	Actual Construction Cost ($)
1	08/2008	03/2009	Operations	6,000	130,000	130,000	1,170,000	1,170,000
2	—	—	Administration, operations	19,000	216,246	291,020	1,889,067	734,440
3	07/2011	04/2013	Operations, maintenance	8,300	120,000	130,000	1,200,000	1,300,000
4	08/2012	06/2013	Operations, vehicle storage	6,720	—	—	277,637	277,637
5	10/2011	12/2012	Operations, vehicle storage	28,000	446,980	550,658	3,980,000	4,594,000
6	10/2011	07/2012	Administration, operations	4,078	—	129,677	1,345,760	1,371,694
7	—	10/2012	Operations, maintenance	5,000	Included in construction		468,000	242,000
8	10/2007	10/2008	Administration, vehicle storage	13,529	105,000	105,000	1,375,000	1,376,223
9	—	02/2014	Administration, maintenance (renovation)	200	—	—	20,000	—
10	—	—	Administration, operations, vehicle storage	36,967	350,000	353,000	3,739,432	3,756,481
11	—	—	Administration, operations, vehicle storage	17,000	250,000	252,632	2,500,000	2,323,192
12	11/2006	08/2008	Operations, maintenance, vehicle storage	8,184	43,600	41,950	545,000	524,312
13	11/2009	02/2010	Administration, operations, maintenance, vehicle storage	29,030	482,000	482,000	4,088,000	4,800,000
14	05/2006	—	Administration, operations, maintenance, vehicle storage	16,500	200,000	—	4,790,000	—
15	04/2000	03/2005	Administration, operations, maintenance, vehicle storage	30,000	129,500	154,370	2,450,000	2,329,000

16	01/2010	Not completed	Administration, operations, maintenance, vehicle storage	70,000	1,500,000	2,000,000	30,000,000	—
17	01/2012	05/2012	Administration, operations, maintenance, vehicle storage	2,000	—	16,600	122,500	133,100
18	09/2012	—	Administration, operations, maintenance, vehicle storage	33,295	450,000	—	6,816,772	—
19	01/2010	06/2011	Administration, operations, maintenance, vehicle storage	40,000	1,586,500	1,586,500	7,557,392	7,872,283
20	05/2011	10/2011	Administration, operations, maintenance, vehicle storage	12,500	—	—	—	—
21	10/2009	Not completed	Administration, operations, maintenance, vehicle storage	75,000	2,000,000	2,000,000	30,000,000	—
22	10/2009	07/2010	Sheltered bus stop	100	6,000	7,500	90,000	128,000
23	09/2011		Sheltered bus stop, sign-only bus stop	30	—	—	6,691	7,531
24	08/2007	03/2010	Administration, operations, maintenance, vehicle storage, park and ride	32,000	—	—	—	—
25	08/2013	—	Administration, operations, maintenance, vehicle storage, small passenger facility, sheltered bus stop, unsheltered bus stop, sign-only bus stop	75,000	95,000	—	950,000	—
26	10/2006	06/2005	Administration, operations, maintenance, vehicle storage, small passenger facility, sheltered bus stop	45,000	70,696	81,686	1,390,762	1,364,494

(sheltered bus stop or sign-only bus stop). Three projects include not only administration, operations, maintenance, and vehicle storage, but also passenger facilities (e.g., park-and-ride facilities, sheltered bus stop, unsheltered bus stop, and sign-only bus stop). Thus, the data were incomplete concerning park-and-ride facilities, sheltered bus stops, unsheltered bus stops, and sign-only bus stops. The cost data that can be used to conduct the analysis only cover those new facilities' construction in the areas of administration, operations, maintenance, and vehicle storage.

However, years for design and construction for eight projects were not provided by respondents. Construction of two projects was not completed until the respondents submitted the surveys. Therefore, design and construction costs for these 10 projects could not be converted to the year of 2014. Eleven projects' estimated and/or actual design costs were missing, and eight projects lacked estimated and/or actual construction costs. Therefore, survey data analysis was conducted based on a limited amount of design and construction cost data.

Before further data analysis was performed, all design and construction cost data were normalized by performing the following two steps. First, all actual design and construction cost data were adjusted from various locations to national average costs by using the city cost index in the *RS Means Building Construction Cost Data* manual. For locations not included in the city cost index, the CNN method was used to estimate cost indexes. Then, the national average costs were adjusted from any previous years to 2014 using the historical cost index in the manual.

Construction Cost Estimating

Table 6 shows estimated, actual, and normalized construction cost data available for conducting the analysis. Facility types are administration, operations, maintenance, and vehicle storage.

The number of projects in the construction cost analysis was 12. The range of normalized construction costs is from \$129,813 to \$8,586,186, and the mean is \$2,437,699. The plot of the normalized construction cost and project size is shown in Figure 6. Regression analysis was performed to identify the relationship between the normalized construction cost and project size for rural and small urban area transit facilities.

The normalized data were fitted with a straight-line regression model at a 90% confidence level. The regression plot and statistical summary are shown in Figure 7.

If construction cost and project size are Y and X respectively, then at a 90% confidence level, the straight-line regression model is $Y = 172.6989\ X$ $(X > 0)$.

Table 6 Construction cost data.

#	Midpoint of Construction	Facility Type	Project Size (sf)	Estimated Construction Cost (\$)	Actual Construction Cost (\$)	Normalized Construction Cost (\$)
1	03/2009	Operations	6,000	1,170,000	1,170,000	1,220,406
2	04/2013	Operations, maintenance	8,300	1,200,000	1,300,000	1,635,071
3	06/2013	Operations, vehicle storage	6,720	277,637	277,637	311,131
4	12/2012	Operations, vehicle storage	28,000	3,980,000	4,594,000	4,201,247
5	07/2012	Administration, operations	4,078	1,345,760	1,371,694	1,444,681
6	10/2012	Operations, maintenance	5,000	468,000	242,000	286,447
7	10/2008	Administration, vehicle storage	13,529	1,375,000	1,376,223	1,627,730
8	08/2008	Operations, maintenance, vehicle	8,184	545,000	524,312	593,875
9	02/2010	Administration, operations, maintenance, vehicle storage	29,030	4,088,000	4,800,000	5,517,413
10	03/2005	Administration, operations, maintenance, vehicle storage	30,000	2,450,000	2,329,000	3,698,384
11	05/2012	Administration, operations, maintenance, vehicle storage	2,000	122,500	133,100	129,813
12	06/2011	Administration, operations, maintenance, vehicle storage	40,000	7,557,392	7,872,283	8,586,186

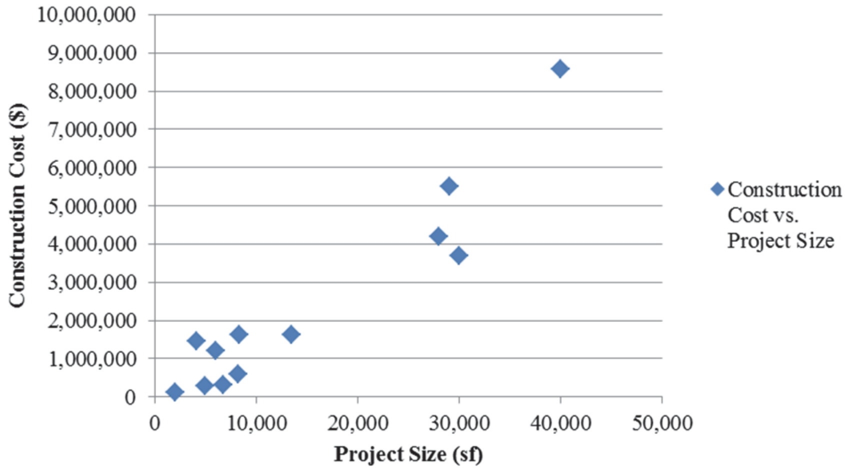


Figure 6 Plot of the normalized construction cost and project size.

In order to prove the necessity of the model, a hypothesis test was conducted at a 90% confidence level. The hypotheses are as follows:

H_0: There is no linear relationship between project size and construction cost.
H_1: There is a positive linear relationship between project size and construction cost.

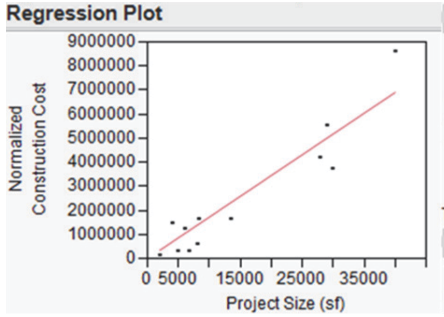
Accordingly, the p-value is $<0.0001 < \alpha = 0.1$. The null hypothesis should be rejected. That is, a straight-line regression model is needed. The $R\text{-square} = \frac{SS_{model}}{SS_{total}} = \frac{1.3637e+14}{1.4494e+14} = 0.940872085$, which indicates that the straight-line regression model is a good fit for the normalized construction cost data.

Percentage of Construction Cost for Each Construction System

In this study, the classification of building elements followed UniFormat II. There are six major group elements: (1) substructure, (2) shell, (3) interiors, (4) services, (5) equipment and furnishings, and (6) special construction and demolition. According to survey results, administration, operations, maintenance facilities, and vehicle storage were combined in most of the rural and small urban area transit projects. Assuming that various combinations of facility types give rise to a different percentage of construction costs for each construction system, projects were categorized into the following two groups: projects including four types of facilities (administration, operations, maintenance, and vehicle storage), and projects including two or three of those facility types (e.g., administration and operations).

Figure 8 shows the percentage breakdown for each construction system for projects with a combination of four types of facilities (administration, operations, maintenance, and vehicle storage). Figure 9 shows the percentage breakdown for each construction system for projects with only two or three types of these facilities.

Regression Plot



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	1.3637e+14	1.364e+14	175.0717
Error	11	8.5685e+12	7.79e+11	Prob > F
C. Total	12	1.4494e+14		<.0001*

Tested against reduced model: Y=0

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Project Size (sf)	172.6989	13.05214	13.23	<.0001*

Figure 7 Construction cost analysis: regression plot and statistical report of straight-line regression. * = statistically insignificant.

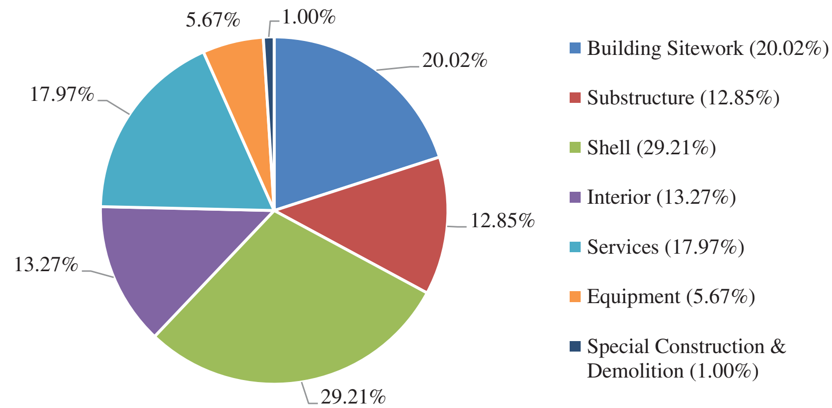


Figure 8 Percentage of construction cost for each construction system (four types of facilities).

Compared with the first combination, the second combination has similar percentages only for substructures and special construction and demolition. Possible reasons for the differences are as follows:

- The larger percentage of building site-work construction cost for the first combination might be due to the necessity of more site mechanical utilities (e.g., water supply and fueling distribution) and more site electrical utilities (e.g., electrical distribution and site lighting) if there were more types of facilities involved in a project.
- The larger percentages of interior and equipment and furnishings construction costs for the first combination might be due to the need for more wall, floor, and ceiling finishes, interior doors, partitions, and furnishings construction if more facility types were included in a project.
- The larger percentages of shell and services construction costs for the second combination might be due to the fact that projects including operations, maintenance, or vehicle storage might require more heating, ventilation, and air conditioning (HVAC), plumbing, and electrical construction to ensure that services or activities can be performed safely and efficiently.

Design Cost Estimating

Table 7 shows the design cost-estimating methods used by respondents to the survey. Most of the design costs of those projects were estimated by using similar projects. Therefore, using regression analysis to find the relationship between design cost and project size should be appropriate in this case.

Table 8 shows estimated, actual, and normalized design cost data available to perform a data analysis. For projects that lacked actual design costs, their

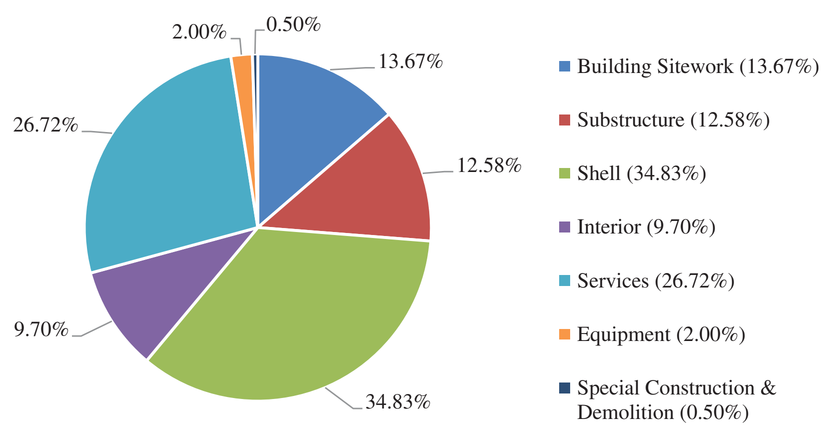


Figure 9 Percentage of construction cost for each construction system (two to three types of facilities).

Table 7 Summary of design cost-estimating methods.

Design Cost-Estimating Method	Number of Projects
Similar projects	11
Hours to design	5
Similar project and hours to design	2
Similar project and historical percentage of construction cost	1
Contractor's estimates	1
Architects' estimates	1
Historical percentage of construction cost	1
Bid	1

estimated design costs were assumed to be the same as the actual design costs. The number of projects in the design cost analysis was 14. The normalized design costs range from \$16,190 to \$2,632,715, and the mean is \$706,533. The plot of design cost versus project size is shown in Figure 10.

The normalized design cost data were fitted with a straight-line regression model with a 90% confidence level. The regression plot and statistical summary are shown in Figure 11.

If design cost and project size are Z and X respectively, then at a 90% confidence level, the straight-line regression model is $Z = 31.635567\ X\ (X > 0)$. In order to prove the necessity of this model, hypothesis test was conducted at a 90% confidence level. The hypotheses are shown as follows:

H_0: There is no linear relationship between project size and design cost.

H_1: There is a positive linear relationship between project size and design cost.

Table 8 Design cost data.

#	Midpoint of Design	Facility Type	Project Size (sf)	Estimated Design Cost ($)	Actual Design Cost ($)	Normalized Design Cost ($)
1	08/2008	Operations	6,000	130,000	130,000	135,375
2	07/2011	Operations, maintenance	8,300	120,000	130,000	172,059
3	10/2011	Operations, vehicle storage	28,000	446,980	550,658	512,536
4	10/2011	Administration, operations	4,078	—	129,677	139,006
5	10/2007	Administration, vehicle storage	13,529	105,000	105,000	132,253
6	11/2006	Operations, maintenance, vehicle storage	8,184	43,600	41,950	52,913
7	11/2009	Administration, operations, maintenance, vehicle storage	29,030	482,000	482,000	564,500
8	05/2006	Administration, operations, maintenance, vehicle storage	16,500	200,000	—	258,787
9	04/2000	Administration, operations, maintenance, vehicle storage	30,000	129,500	154,370	307,382
10	01/2010	Administration, operations, maintenance, vehicle storage	70,000	1,500,000	2,000,000	2,583,935
11	01/2012	Administration, operations, maintenance, vehicle storage	2,000	—	16,600	16,190
12	09/2012	Administration, operations, maintenance, vehicle storage	33,295	450,000	—	580,831
13	01/2010	Administration, operations, maintenance, vehicle storage	40,000	1,586,500	1,586,500	1,802,982
14	10/2009	Administration, operations, maintenance, vehicle storage	75,000	2,000,000	2,000,000	2,632,715

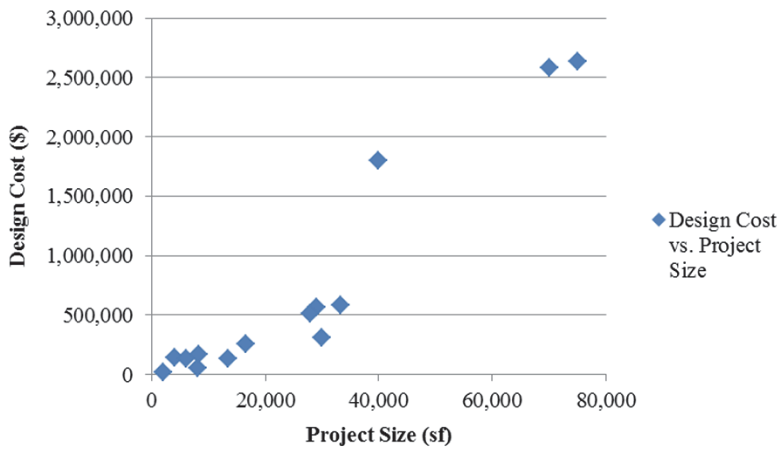


Figure 10 Design cost versus project size.

Accordingly, the p-value is $0.0001 < \alpha = 0.1$. The null hypothesis should be rejected. That is, a straight-line regression model is needed. The $R\text{-square} = \frac{SS_{model}}{SS_{total}} = \frac{1.6421e+13}{1.8027e+13} = 0.910911411$, which indicates that the straight-line regression model is a good fit for the normalized design cost data.

Risk Analysis

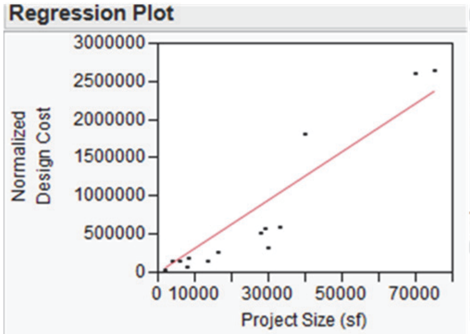
The frequency of the risk factors stated by survey participants is shown in Figure 12. Soil conditions and unexpected underground conditions are two of the most frequent risk factors, and most interviewees also suggested these two risks. Contaminated soil, buried debris, and unexpected utilities can increase project costs and also cause unanticipated delays during construction. Compared with the interview results concerning risks, the survey respondents also considered risk factors, including high project complexity, omissions and errors in design, and shortage of construction materials. Not recognizing a project's high complexity will cause some criteria for a project not to be met during the decision process, and contingency will not be estimated at a proper level. Design omissions and errors and shortage of construction materials can cause cost overruns and construction delays. However, the survey respondents did not think of the archaeological requirements of local government as a risk.

Although some respondents suggested risk factors in the survey, their projects did not experience cost overruns. The reasons could be that there was sufficient contingency in the estimated construction cost or that project control plans were carried out effectively by the project management teams.

Contingency Estimating

Although 21 out of 26 respondents stated that a percentage of construction cost was used to esti-

Regression Plot



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	1.6421e+13	1.642e+13	132.9848
Error	13	1.6053e+12	1.235e+11	Prob > F
C. Total	14	1.8027e+13		<.0001*

Tested against reduced model: Y=0

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Project Size (sf)	31.635567	2.743308	11.53	<.0001*

Figure 11 Design cost analysis: regression plot and statistical report of straight-line regression. * = statistically insignificant.

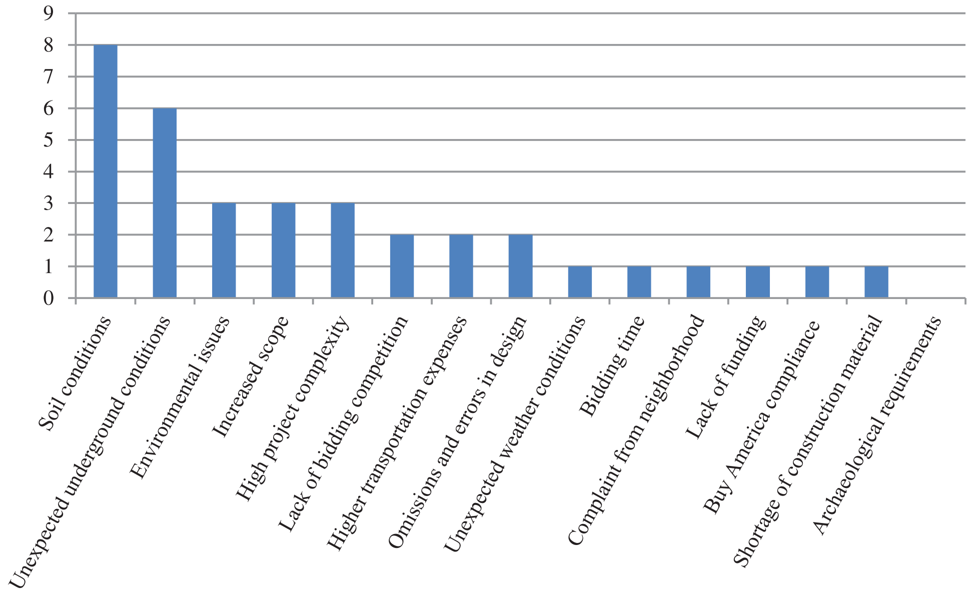


Figure 12 Frequency of the risk factors.

mate contingency, only eight of them provided the percentages they used. Contingency percentage provided by the respondents ranges from 4% to 15%. The average contingency is 9.5%, and the median of contingency is 10%.

Chapter Summary

This chapter first described the survey protocol development and survey process. Then, regression functions to predict design and construction costs were identified and verified. Risk factors and contingency estimating for rural and small urban area transit facility projects were discussed. The analysis results supported the development of the cost estimating database and prototype tool, which is the subject of the next chapter.

CHAPTER 6 DEVELOPMENT OF THE COST ESTIMATING DATABASE AND PROTOTYPE TOOL FOR RURAL AND SMALL URBAN AREA TRANSIT FACILITIES

Cost Estimating Database Development

After gathering and classifying actual historical cost data through surveys, all data were input into an Excel spreadsheet and were adjusted to national average costs for 2014 by using the 2014 version of the *RS Means Building Construction Cost Data* manual. The database is limited by the amount of cost data collected through the online survey. The facility types covered in this database include administration, operations, maintenance, and vehicle storage, but the types exclude passenger facilities (small and large), park-and-ride facilities, bus stops (sheltered and unsheltered), and sign-only bus stops. Most projects in the database are combinations of administration, operations, maintenance, and vehicle storage. The cost estimating database was constructed excluding land acquisition and had the following features:

- Basic project information: city, state, the midpoint of design time (month/year), the midpoint of construction time (month/year), location (rural/small urban), and facility type.
- Project duration: design duration (month) and construction duration (month).
- Cost information: project size (sf), estimated design cost ($), estimated construction cost ($), actual design cost ($), and actual construction cost ($).
- Percentage of construction cost for each construction system: building site work (%), substructure (%), shell (%), interiors (%), equipment and furnishings (%), and special construction and demolition (%).

Screen captures of the database are shown in Figure 13, Figure 14, and Figure 15.

#	City	State	Mid-point of Design	Mid-point of Construction	Location	Facility Type	Design Duration (month)	Construction Duration (month)
			Basic Project Information				**Project Duration**	
1	Fremont	Ohio			Rural	Administration,Operation,Vehicle Storage	16	16
2	Oak Harbor	Ohio			Rural	Administration,Operation,Vehicle Storage	8	11
3	Ephrata	Washington	11/2009	02/2010	Rural	Administration,Operation,Maintenance,Vehicle Storage	4	14
4	Hoquiam	Washington			Rural	Administration,Operation	6	7
5	Wilmington	Vermont	05/2006		Rural	Administration,Operation,Maintenance,Vehicle Storage	26	
6	Mason City	Iowa	04/2000	03/2005	Rural	Administration,Operation,Maintenance,Vehicle Storage	12	14
7	Columbia City	Indiana	08/2012	06/2013	Rural	Operation, Vehicle Storage	0	10
8	Lowry	Minnesota	11/2006	08/2008	Rural	Operation,Maintenance,Vehicle Storage	6	6
9	Attleboro	Massachusetts	10/2011	12/2012	Small Urban	Operation, Vehicle Storage	14	13
10	Manitowoc	Wisconsin	10/2011	07/2012	Rural	Administration, Operation	6	8
11	Park City	Utah		10/2012	Rural	Operation, Maintenance		4
12	Jackson	Wyoming	01/2010	05/2014	Rural	Administration,Operation,Maintenance,Vehicle Storage	82	14
13	Solvang	California	01/2012	05/2012	Rural	Administration,Operation,Maintenance,Vehicle Storage	2	4
14	Fresno	California	08/2008	03/2009	Small Urban	Operation	4	7
15	Grand Forks	North Dakota	09/2012		Small Urban	Administration,Operation,Maintenance,Vehicle Storage	27	
16	Butler	Pennsylvania	01/2010	06/2011	Small Urban	Administration,Operation,Maintenance,Vehicle Storage	15	11
17	Fort Defiance	Arizona	05/2011	10/2011	Rural	Administration,Operation,Maintenance,Vehicle Storage	2	12
18	Oxford	Mississippi	07/2011	04/2013	Rural	Operation,Maintenance	36	10
19	Jackson	Wyoming	10/2009	11/2015	Small Urban	Administration,Operation,Maintenance,Vehicle Storage	90	51
20	Sidney	Ohio	10/2007	10/2008	Rural	Administration,Vehicle Storage	6	8

Figure 13 Cost estimating database—basic project information and project duration.

#	City	State	Project Size (sf)	Estimated Design Cost ($)	Actual Design Cost ($)	Estimated Construction Cost ($)	Actual Construction Cost($)	Bu
			Cost Information					
1	Fremont	Ohio	36,967					
2	Oak Harbor	Ohio	17,000					
3	Ephrata	Washington	29,030	564,500	564,500	4,698,997	5,517,413	
4	Hoquiam	Washington	19,000					
5	Wilmington	Vermont	16,500	258,787				
6	Mason City	Iowa	30,000	257,861	307,382	3,890,528	3,698,384	
7	Columbia City	Indiana	6,720			311,131	311,131	
8	Lowry	Minnesota	8,184	54,994	52,913	617,308	593,875	
9	Attleboro	Massachusetts	28,000	416,035	512,536	3,639,739	4,201,247	
10	Manitowoc	Wisconsin	4,078		139,006	1,417,367	1,444,681	
11	Park City	Utah	5,000	Included in construction	Included in construction	553,954	286,447	
12	Jackson	Wyoming	70,000	1,937,951	2,583,935			
13	Solvang	California	2,000		16,190	119,475	129,813	
14	Fresno	California	6,000	135,375	135,375	1,220,406	1,220,406	
15	Grand Forks	North Dakota	33,295	580,831				
16	Butler	Pennsylvania	40,000	1,802,982	1,802,982	8,242,739	8,586,186	
17	Fort Defiance	Arizona	12,500					
18	Oxford	Mississippi	8,300	158,823	172,059	1,509,296	1,635,071	
19	Jackson	Wyoming	75,000	2,632,715	2,632,715	39,425,059		
20	Sidney	Ohio	13,529	132,253	132,253	1,626,284	1,627,730	

Figure 14 Cost estimating database—project cost information.

#	City	State	Building Sitework (%)	Substructure (%)	Shell (%)	Interiors (%)	Services (%)	Equipment & Furnishings (%)	Special Construction & Demolition (%)
			Percentage of Construction Cost for Each Building Element						
1	Fremont	Ohio	14	4	35	3	42	1	1
2	Oak Harbor	Ohio	16	9	30	13	30	2	0
3	Ephrata	Washington	15	10	35	15	20	5	0
4	Hoquiam	Washington							
5	Wilmington	Vermont	23	7	30	5	21	11	4
6	Mason City	Iowa	29.8	17.4	17.4	17.4	18.2	0	0
7	Columbia City	Indiana	0	17.5	62.0	7.2	13.3	0	0
8	Lowry	Minnesota	20	10	40	3	25	0	2
9	Attleboro	Massachusetts							
10	Manitowoc	Wisconsin							
11	Park City	Utah							
12	Jackson	Wyoming							
13	Solvang	California	23	3	30	11	23	11	0
14	Fresno	California							
15	Grand Forks	North Dakota	25	15	25	15	7	10	3
16	Butler	Pennsylvania	15	5	47	15	15	3	0
17	Fort Defiance	Arizona							
18	Oxford	Mississippi	20	20	20	20	15	5	0
19	Jackson	Wyoming	10	33	20	15	22	0	0
20	Sidney	Ohio	12	15	22	12	35	4	0

Figure 15 Cost estimating database—percent of construction cost for each construction system.

Cost Estimating Prototype Tool Development

The types of rural and small urban area transit facilities include administration, operations, maintenance, vehicle storage, park and ride, sheltered bus stops, unsheltered bus stops, and sign-only bus stops. The historical cost data collected to develop the database in support of this prototype tool cover only those facilities in the administration, operations, maintenance, and vehicle storage types due to incomplete data concerning the last four types. Generally speaking, administration, operations, maintenance, and vehicle storage were combined in most of the projects included in the database. Thus, the prototype tool was developed based on project size and costs for the combination of these facility types.

The tool is considered a prototype due to this lack of historical cost data collected and used to develop the cost estimating database (only 12 to 14 projects with complete historical data). The database was developed in Excel and consists of five tabs: Introduction, User's Guide, Project Information, Estimates Report, and Estimates Details. Each tab is described in detail with its screen capture.

Introduction

The cost estimating prototype tool is an Excel file. Once the user opens the tool, the Introduction tab will be shown. In order to ensure that the tool works properly, the user is asked to read the introduction with care before starting the user's cost estimating process. The screen captures of the introduction section are shown in Figure 16.

As the first section of the estimating tool, the introduction section introduces the research background, the objectives of the cost estimating prototype tool, types of facilities considered, tips for navigation and document saving, and copyright information.

User's Guide

The User's Guide tab explains how to use the tool and contains tips for using the tool. The section includes five aspects: how to navigate the tool, how to save and print the results of the estimate, how to input project information, how to set variables (e.g., inflation rate, contingency percentage, and location adjustment factor), and how to interpret the estimate report.

The tool supports cost estimating from year 2015 to year 2025. The tool suggests that the user should

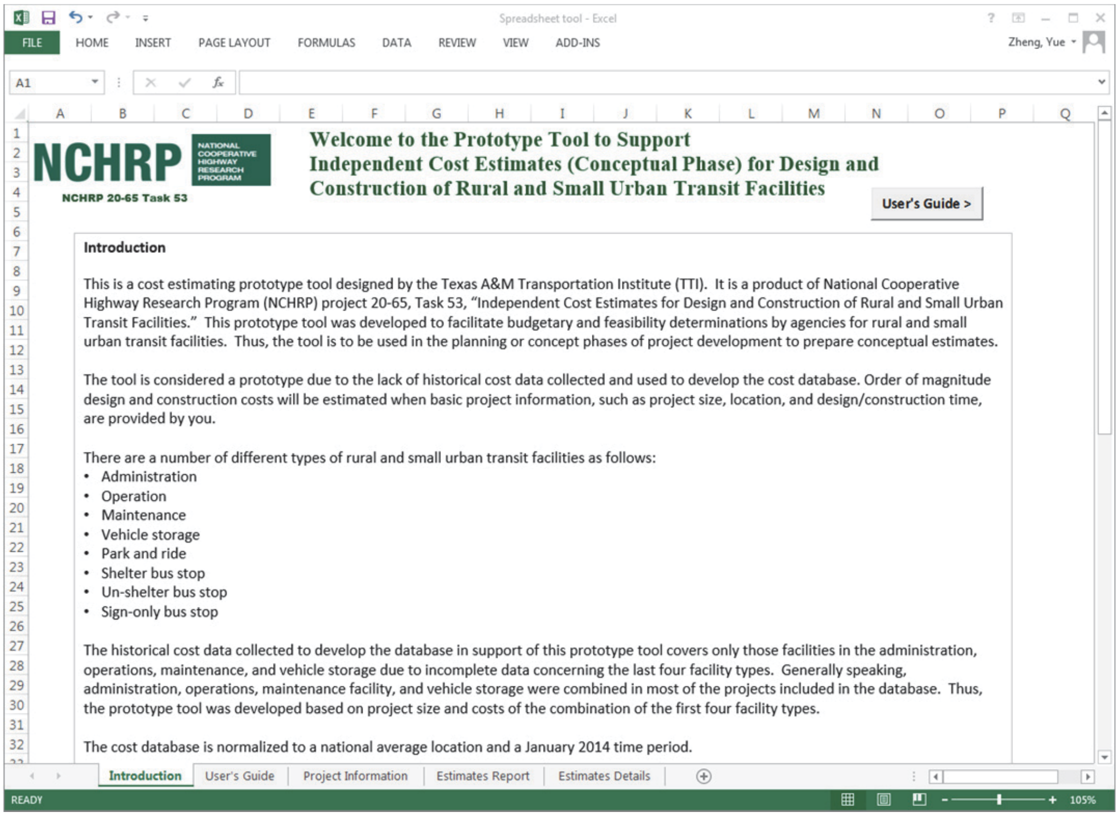


Figure 16 (A) Screen capture of the Cost Estimating Prototype Tool—Introduction.

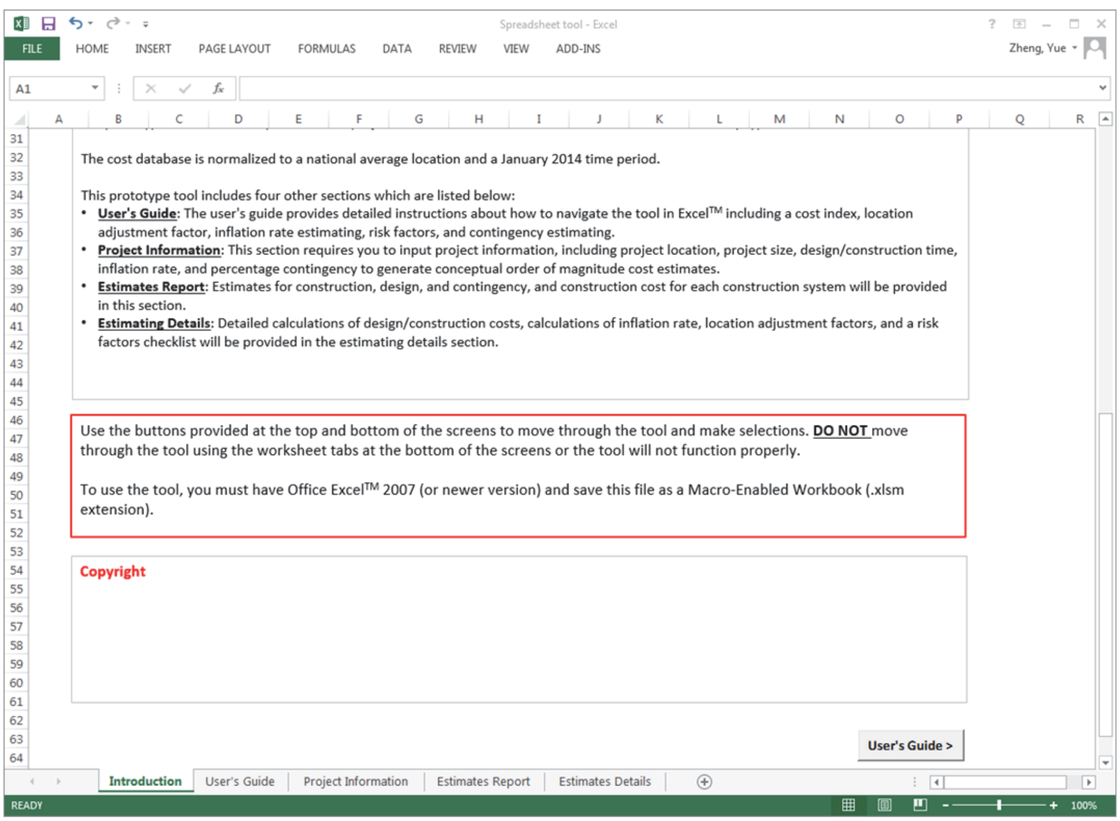


Figure 16 (B) Screen capture of the Cost Estimating Prototype Tool—Introduction (continued).

carefully evaluate any estimates made using this tool after the 5-year mark (after 2020). Users can either choose the default inflation rate (2.5%) or input a value based on their knowledge of local economic conditions. The default inflation rate was set after consulting two experts in cost estimating.

In this prototype tool, contingency is estimated as a percentage of construction cost. Users can either choose the default percentage range or input a contingency percentage based on their knowledge of the project scope, uncertainties such as site conditions, and other project characteristics that may influence a project's costs. The default range of contingency is 10% to 25%, and the most likely contingency percentage is 15%. The default contingency percentages were set by the experts in cost estimating based on the results of interviews and online surveys and their estimating experience. Before setting contingency, the tool recommends that the user assess the risk factors listed in the tool to ensure that a sufficient amount of contingency is estimated.

As for the location adjustment factor, the estimating prototype tool has 10 regions within the United States, based on the 10 standard federal regions established by the Office of Management and Budget (1974). For each region, 20 cities, including large and small cities, were selected, and cost indexes of those cities from the 2014 version of the *RS Means Building Construction Cost Data* manual were used to calculate the location factor. The chosen cities, population, and cities' indexes are located in Appendix F. The location adjustment factor for each region is listed in Table 9. The index of the national average is 100. The prototype tool uses the following equation to adjust design and construction costs from the national average to any particular region.

$$\frac{\text{Cost at national average}}{100} \times \text{Region's index number}$$

The screen captures of this section are shown in Figure 17. After reading the section, the user can go to the Project Information tab by clicking the Continue button.

Project Information

The Project Information tab enables the user to input the project information necessary to generate an estimate report: agency name/type, project name/owner, project construction location, estimated midpoint of the design and construction duration, order of magnitude of project size (sf), inflation rate, contingency percent, and date. The screen captures of this tab are shown in Figure 18. For the user's reference, the tool provides the user default values for the inflation rate and contingency percentage (lower boundary, most likely, and upper boundary). However, users can also input the values of those variables based on their knowledge of the project. To help the user estimate a proper range of contingency percentages, suggestions are provided. Figure 18 B and C show the screen captures of the suggestions. After completing the project information, the user can go to the Estimates Report tab to review the estimate results by clicking the Calculate and Continue button.

Table 9 Regions and location adjustment factors.

Region	Location Adjustment Factor
Region I: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	103.1
Region II: New Jersey, New York, Puerto Rico, Virgin Islands	107.6
Region III: Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia	96.0
Region IV: Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee	80.3
Region V: Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin	99.5
Region VI: Arkansas, Louisiana, New Mexico, Oklahoma, Texas	83.3
Region VII: Iowa, Kansas, Missouri, Nebraska	91.6
Region VIII: Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming	86.7
Region IX: Arizona, California, Hawaii, Nevada	102.0
Region X: Alaska, Idaho, Oregon, Washington	102.1

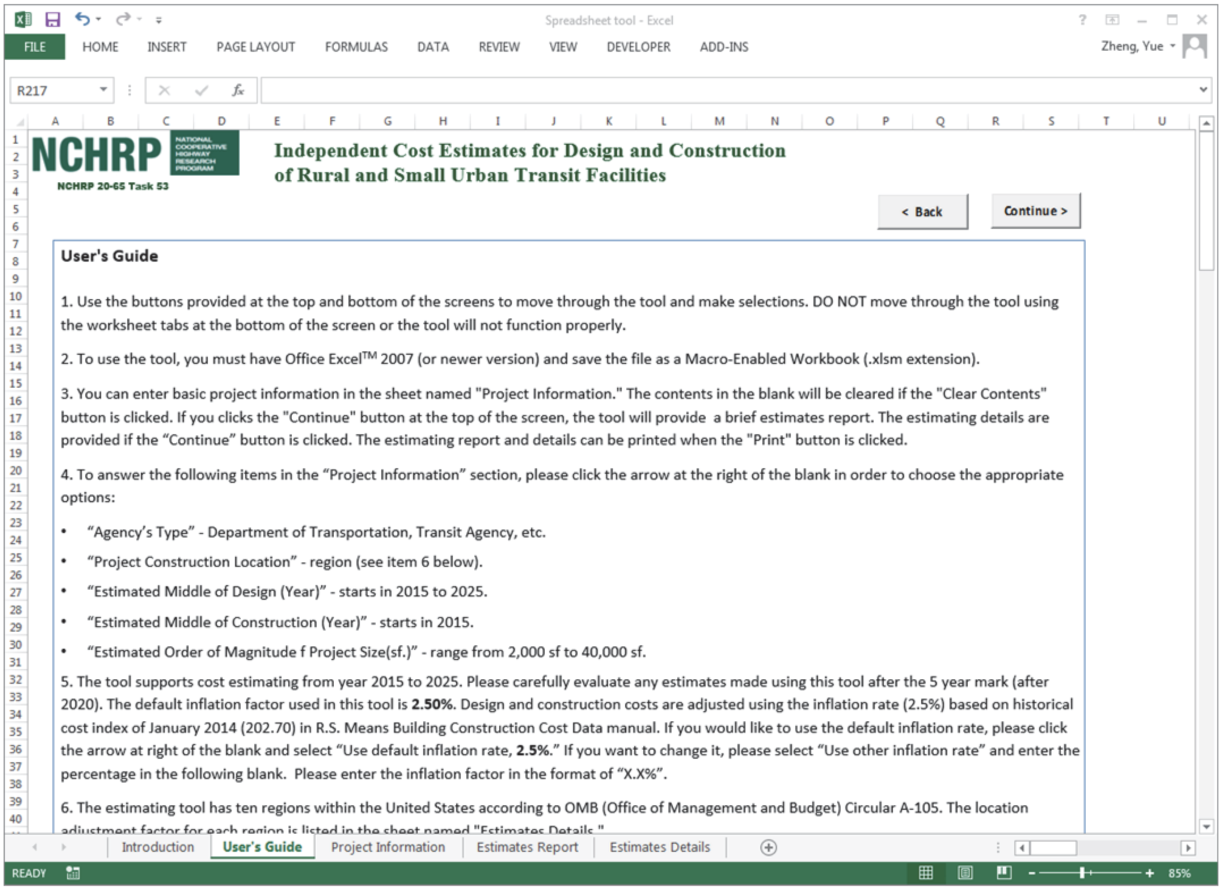


Figure 17 (A) Screen capture of the Cost Estimating Prototype Tool—User's Guide.

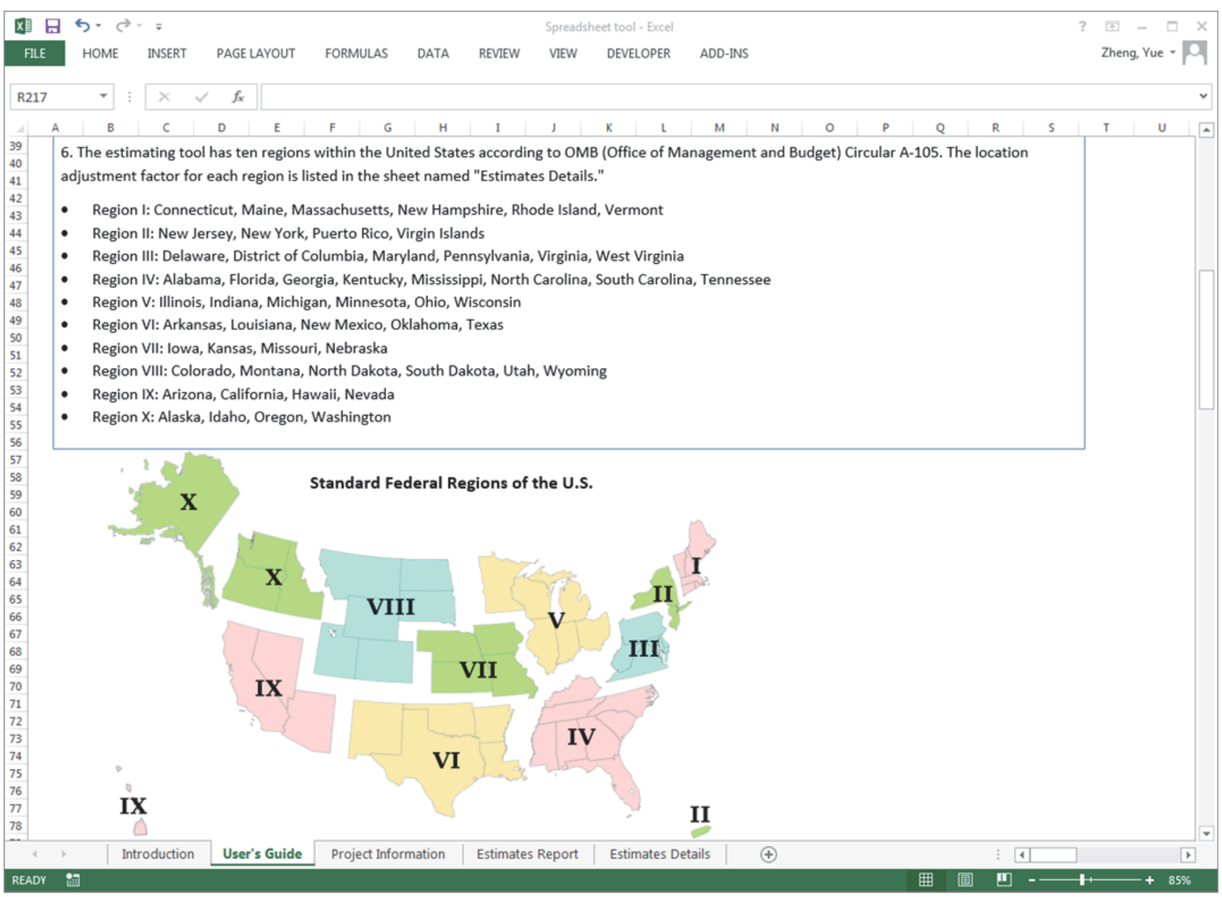


Figure 17 (B) Screen capture of the Cost Estimating Prototype Tool—User's Guide (continued).

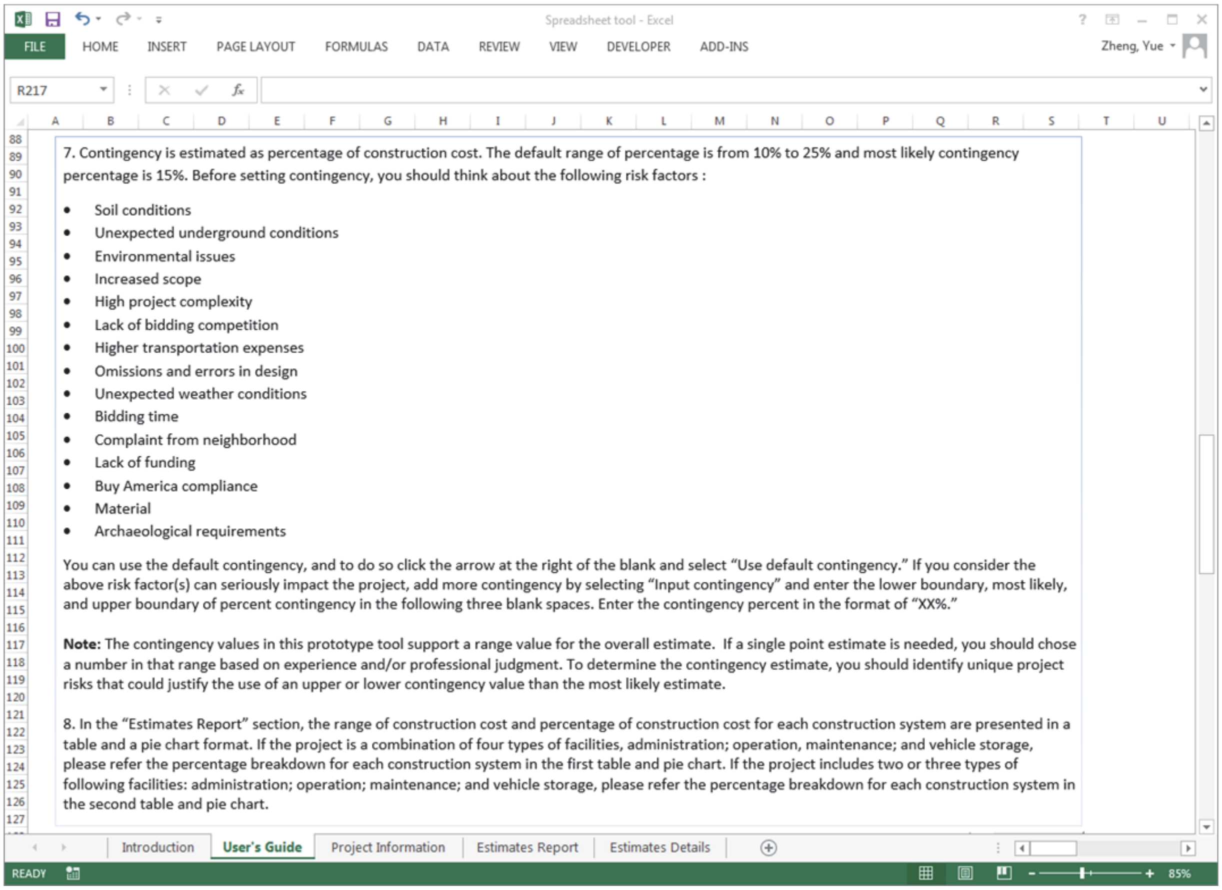


Figure 17 (C) Screen capture of the Cost Estimating Prototype Tool—User's Guide (continued).

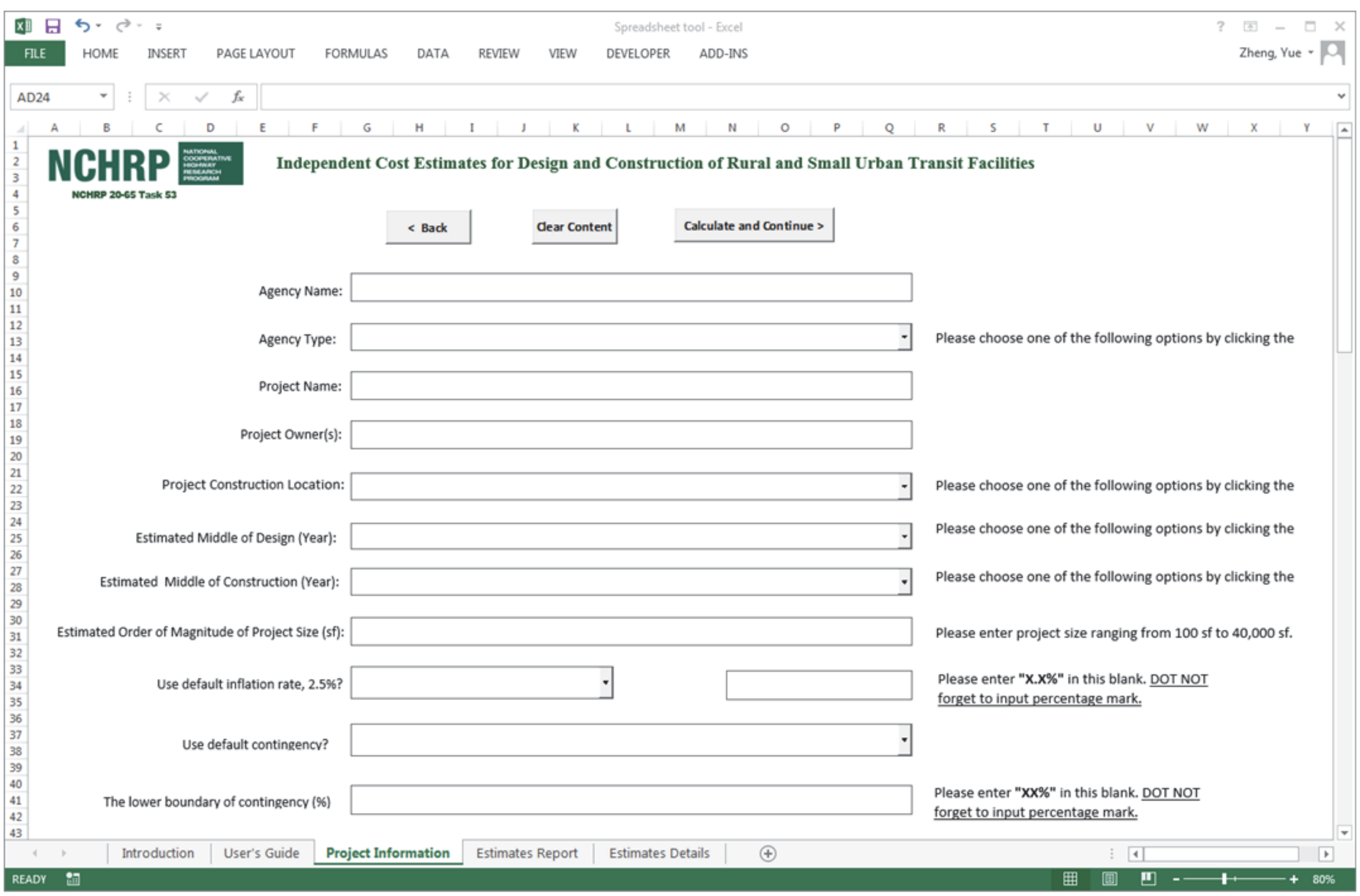


Figure 18 (A) Screen capture of the Cost Estimating Prototype Tool—Project Information.

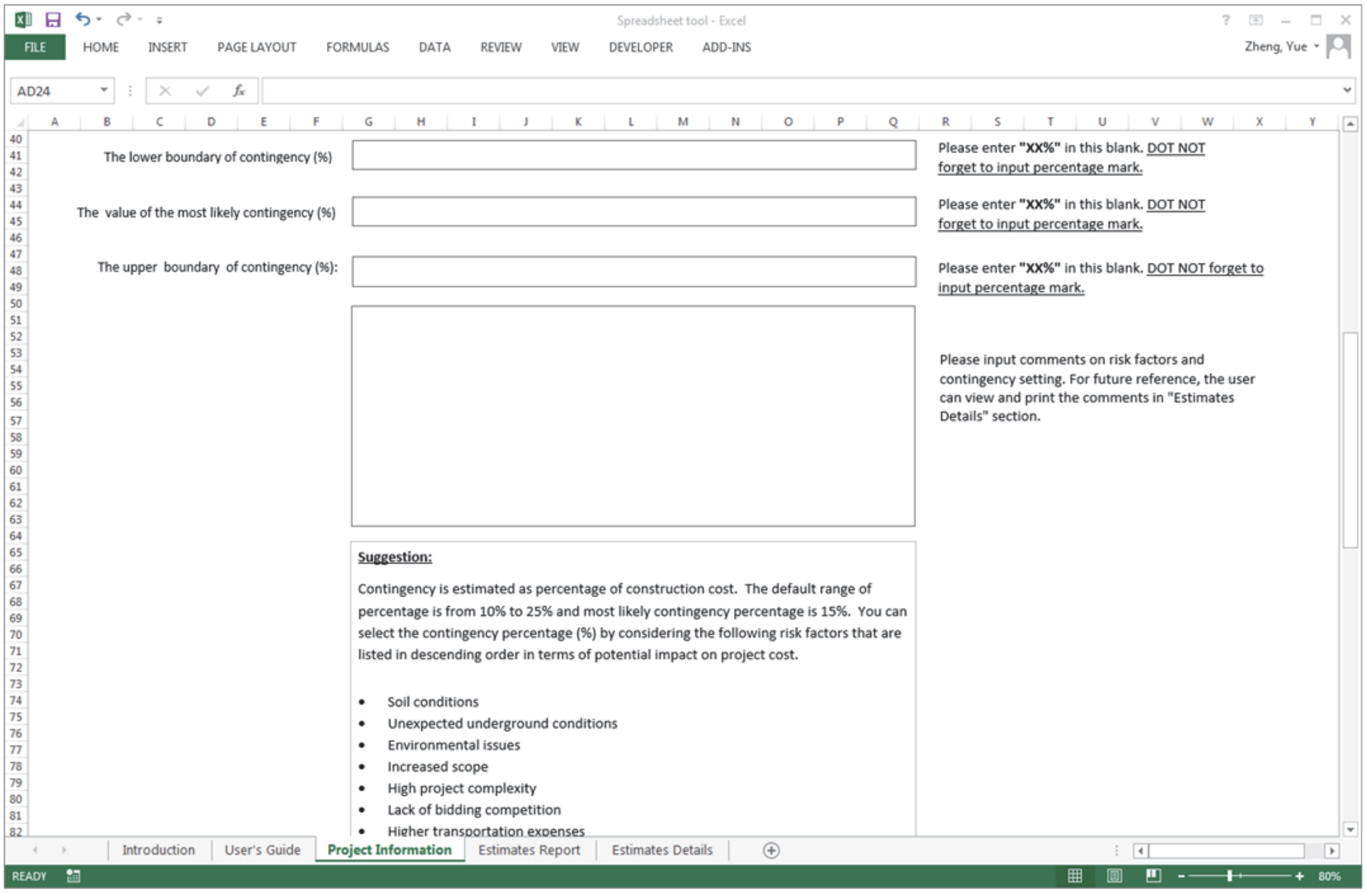


Figure 18 (B) Screen capture of the Cost Estimating Prototype Tool—Project Information (continued).

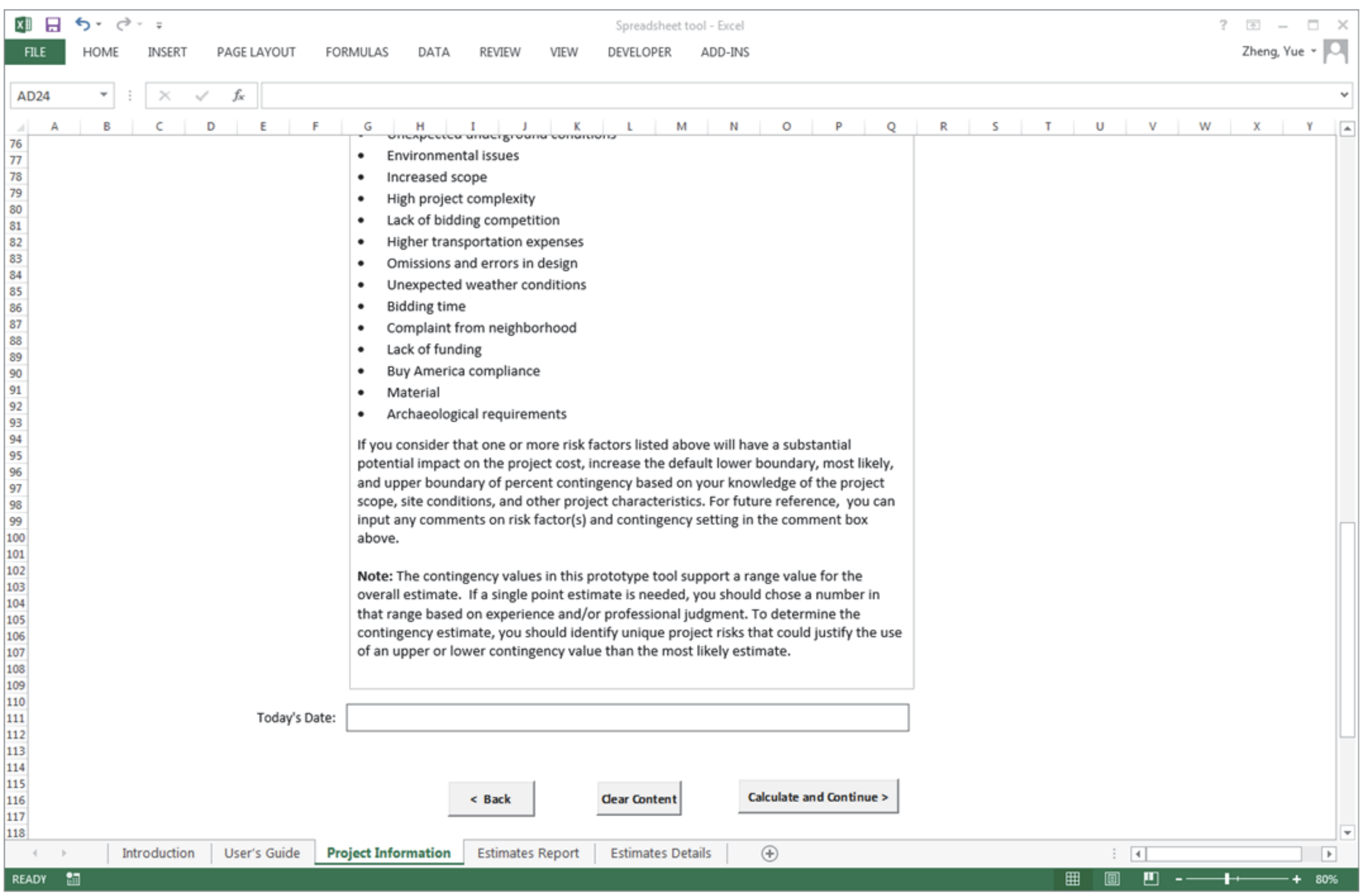


Figure 18 (C) Screen capture of the Cost Estimating Prototype Tool—Project Information (continued).

Estimates Report

The Estimates Report tab generates the estimates based on the user's input. Estimate information includes base construction cost ($), range of contingency ($), range of total construction cost ($), design cost ($), and construction cost for each construction system. The construction base estimate and design costs, exclusive of project contingency, are estimated by using the regression functions described in Chapter 5. The base construction cost and contingency add up to the total construction cost.

The screen captures of this tab are shown in Figure 19. The user can print the report by clicking the Print button at the top of the screen. To review estimate details, the user should click "Continue" to go to the Estimates Details tab.

Estimates Details

The Estimates Details tab provides the user with the detailed calculations of the estimate and the historical index information. The user can also review the location factor for each region, risk factors, and any comments the user input in the Project Information tab. The screen captures of this tab are shown in Figure 20. The user can print information in this tab by clicking the Print button.

Review of the Cost Estimating Tool

The purpose of the review was to ensure the self-explanation, functionality, and user-friendliness of the prototype tool. The prototype tool was not tested for the accuracy of its estimates due to the limited

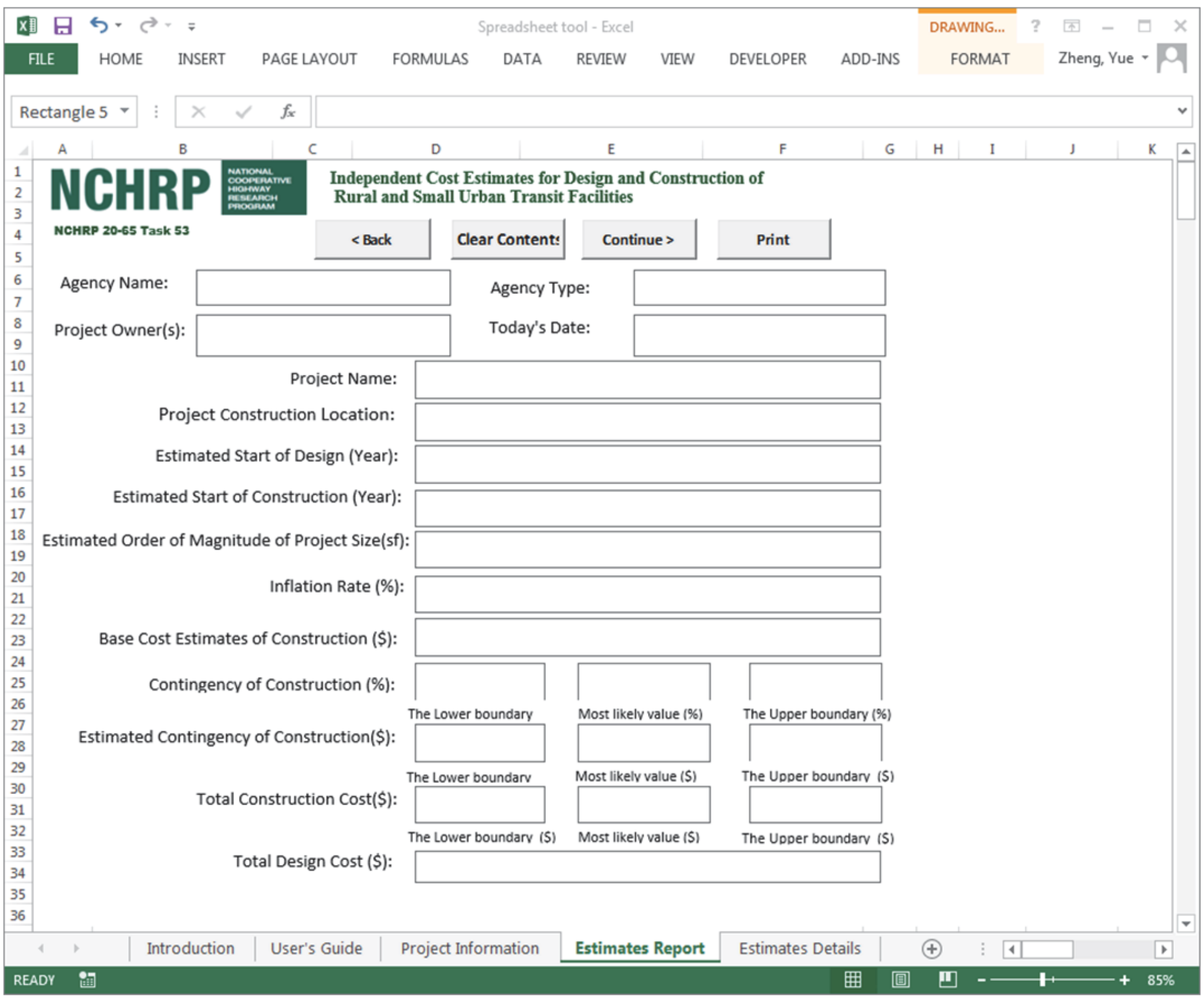
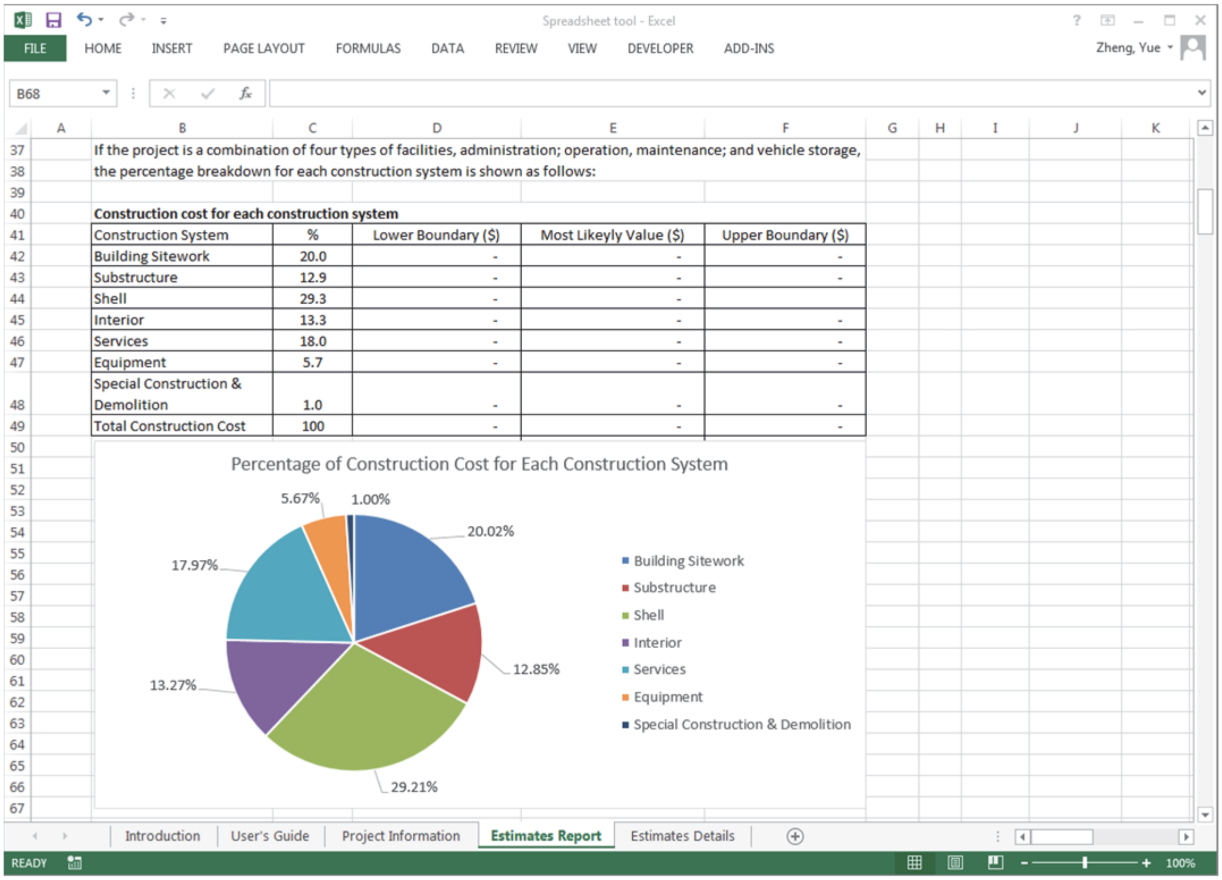


Figure 19 (A) Screen capture of the Cost Estimating Prototype Tool—Estimates Report.

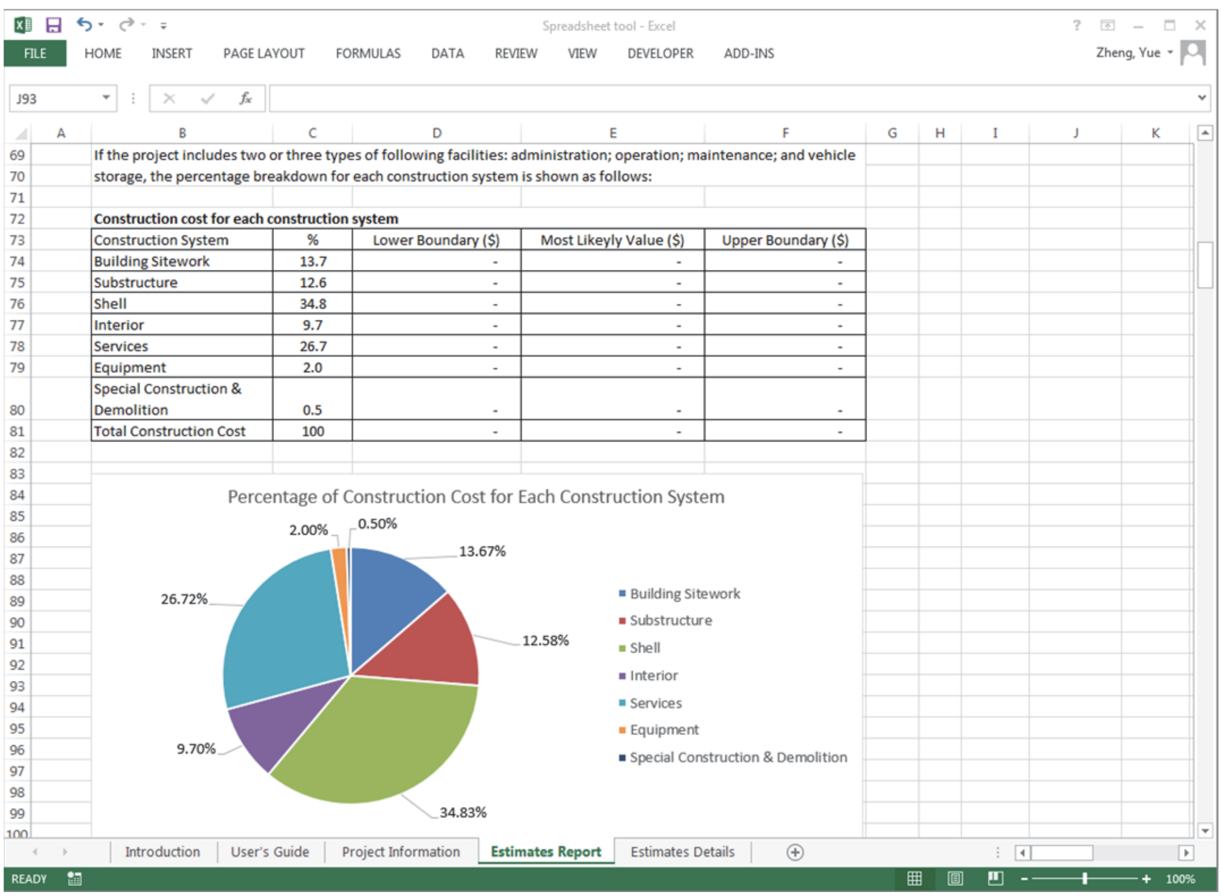


If the project is a combination of four types of facilities, administration; operation, maintenance; and vehicle storage, the percentage breakdown for each construction system is shown as follows:

Construction cost for each construction system

Construction System	%	Lower Boundary ($)	Most Likelyly Value ($)	Upper Boundary ($)
Building Sitework	20.0	-	-	-
Substructure	12.9	-	-	-
Shell	29.3	-	-	
Interior	13.3	-	-	-
Services	18.0	-	-	-
Equipment	5.7	-	-	-
Special Construction & Demolition	1.0	-	-	-
Total Construction Cost	100	-	-	-

Figure 19 (B) Screen capture of the Cost Estimating Prototype Tool—Estimates Report (continued).



If the project includes two or three types of following facilities: administration; operation; maintenance; and vehicle storage, the percentage breakdown for each construction system is shown as follows:

Construction cost for each construction system

Construction System	%	Lower Boundary ($)	Most Likelyly Value ($)	Upper Boundary ($)
Building Sitework	13.7	-	-	-
Substructure	12.6	-	-	-
Shell	34.8	-	-	-
Interior	9.7	-	-	-
Services	26.7	-	-	-
Equipment	2.0	-	-	-
Special Construction & Demolition	0.5	-	-	-
Total Construction Cost	100	-	-	-

Figure 19 (C) Screen capture of the Cost Estimating Prototype Tool—Estimates Report (continued).

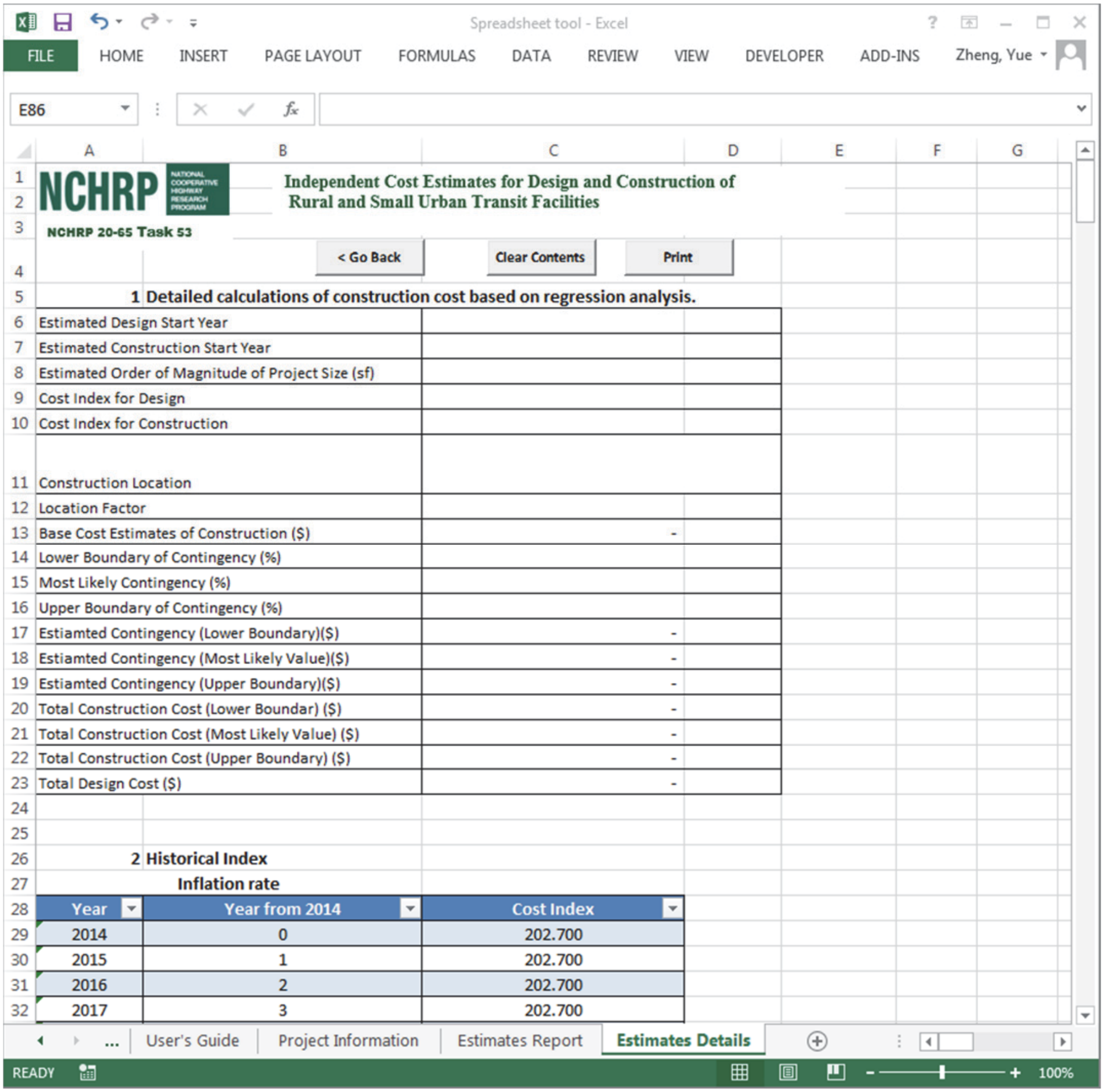


Figure 20 (A) Screen capture of the Cost Estimating Prototype Tool—Estimates Details.

database. Throughout the cost estimating prototype tool's development, two cost estimating experts provided consistent help and reviewed and tested the prototype tool. They recommended that the contingency be estimated as a range, with high, most likely, and low values rather than as a specific value during the conceptual estimating phase. Therefore, the contingency estimating method suggested by Olumide et al. (2010) was used in this estimating prototype tool. The default range of contingency in the tool was set based on their estimating expertise and the interview and survey results. The default inflation rate was determined based on the experts' judgment of the economic conditions and prediction of labor and material costs of the building construction industry. After consultation, the projects were classified into two categories. The reasons behind this classification were that administration, operations, maintenance, and vehicle storage are combined in most of the projects for which information was collected through the online survey, and different combinations have a different percentage

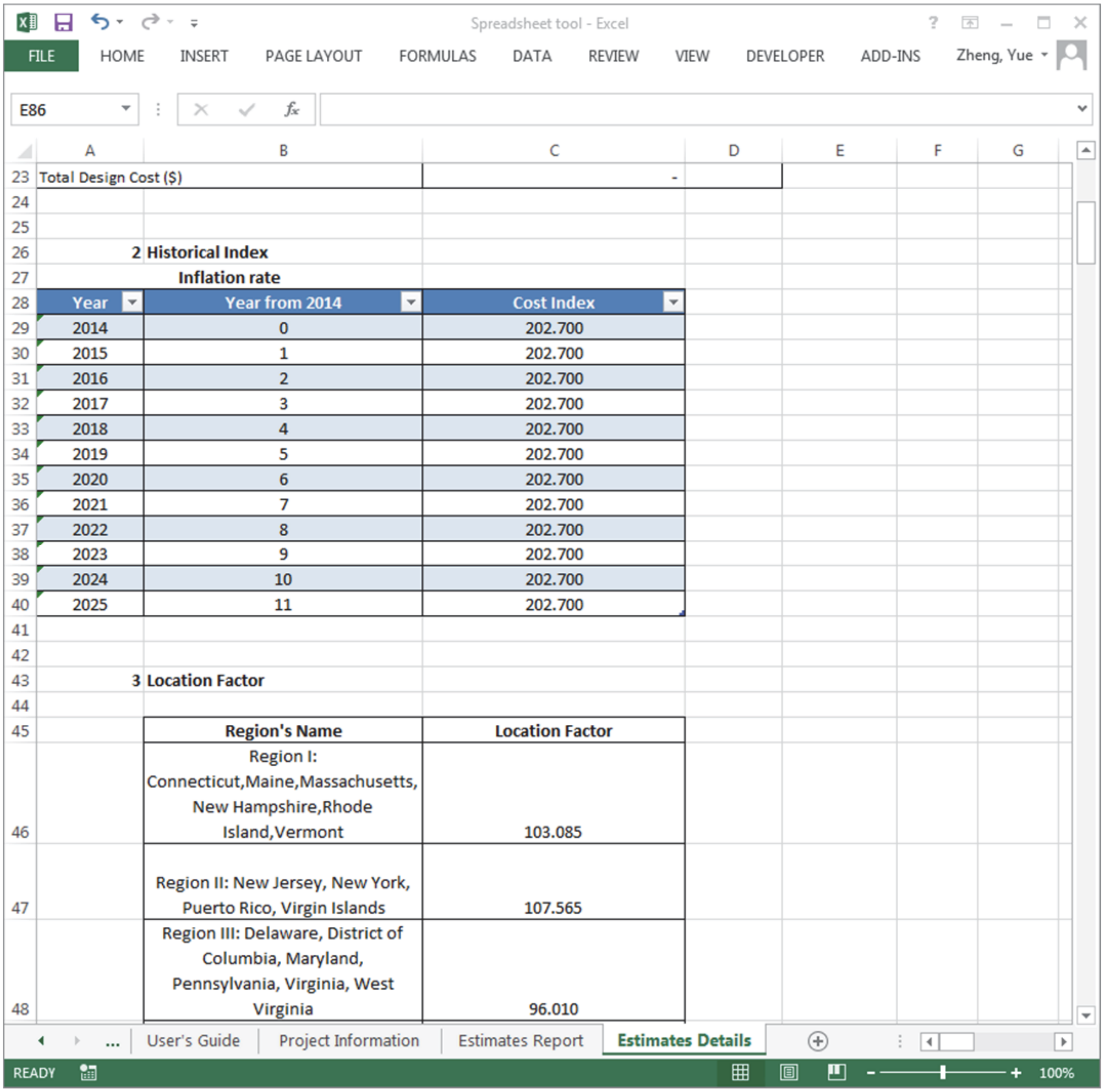


Figure 20 (B) Screen capture of the Cost Estimating Prototype Tool—Estimates Details (continued).

breakdown for each construction system. In this way, the difference of percentage breakdown of different combinations can be reflected to some degree. The Introduction and User's Guide tabs were also revised based on the experts' comments.

The protocol, including a research memorandum and a list of questions, was sent to reviewers for comments and suggestions. The protocol is provided in Appendix G. Both the protocol and prototype tool were sent to two DOT personnel and three transit managers through emails on May 16, 2014. Follow-up emails were sent on May 28, 2014. One response from a transit manager was received. The respondent did not experience any difficulty in navigating through the tool, understanding the user's guide, and completing the project information section. The estimate details section was helpful for the respondent to understand adjustment factors and calculations of design and construction costs.

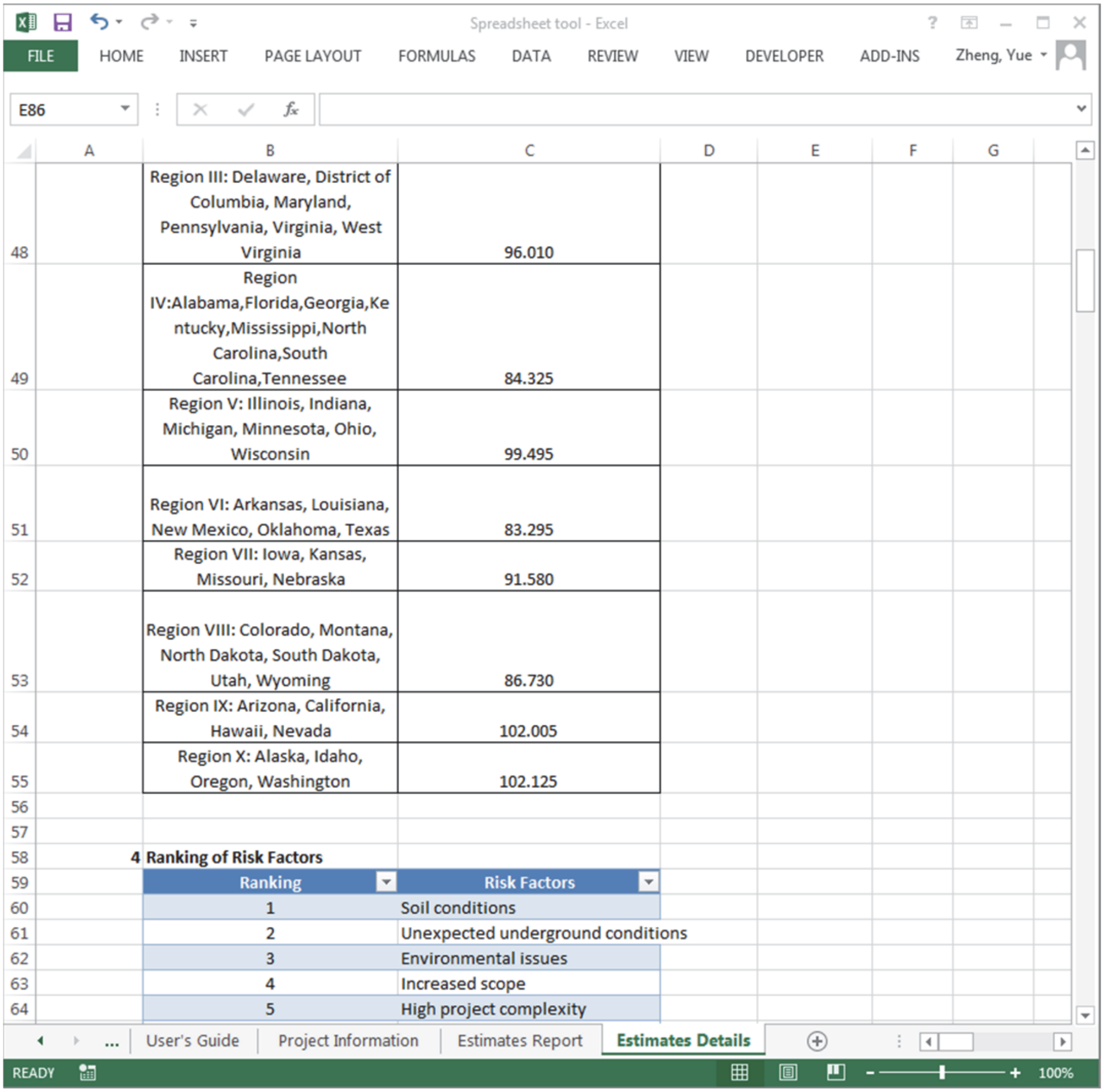


Figure 20 (C) Screen capture of the Cost Estimating Prototype Tool—Estimates Details (continued).

Moreover, an Excel file including a list of rural transit facility projects constructed in Texas was provided by the Texas Transportation Institute (TTI). Project size, year of construction, location, and cost were included in the file. However, this file did not explicitly explain what the costs represented (e.g., total construction cost, design costs, or estimated total construction costs). Assuming that the costs listed in the file were total construction costs, the projects were used to evaluate the appropriateness of the construction cost estimates produced by the prototype tool. Default inflation rate and range of contingency percentage were used in the evaluation test. Although some construction cost estimates calculated by the prototype tool were similar to the costs provided in the TTI file, other estimates had great differences. The differences might be due to the fact that the costs in the file were not exact total construction costs, or there might have been some mistakes made when the project cost data were documented.

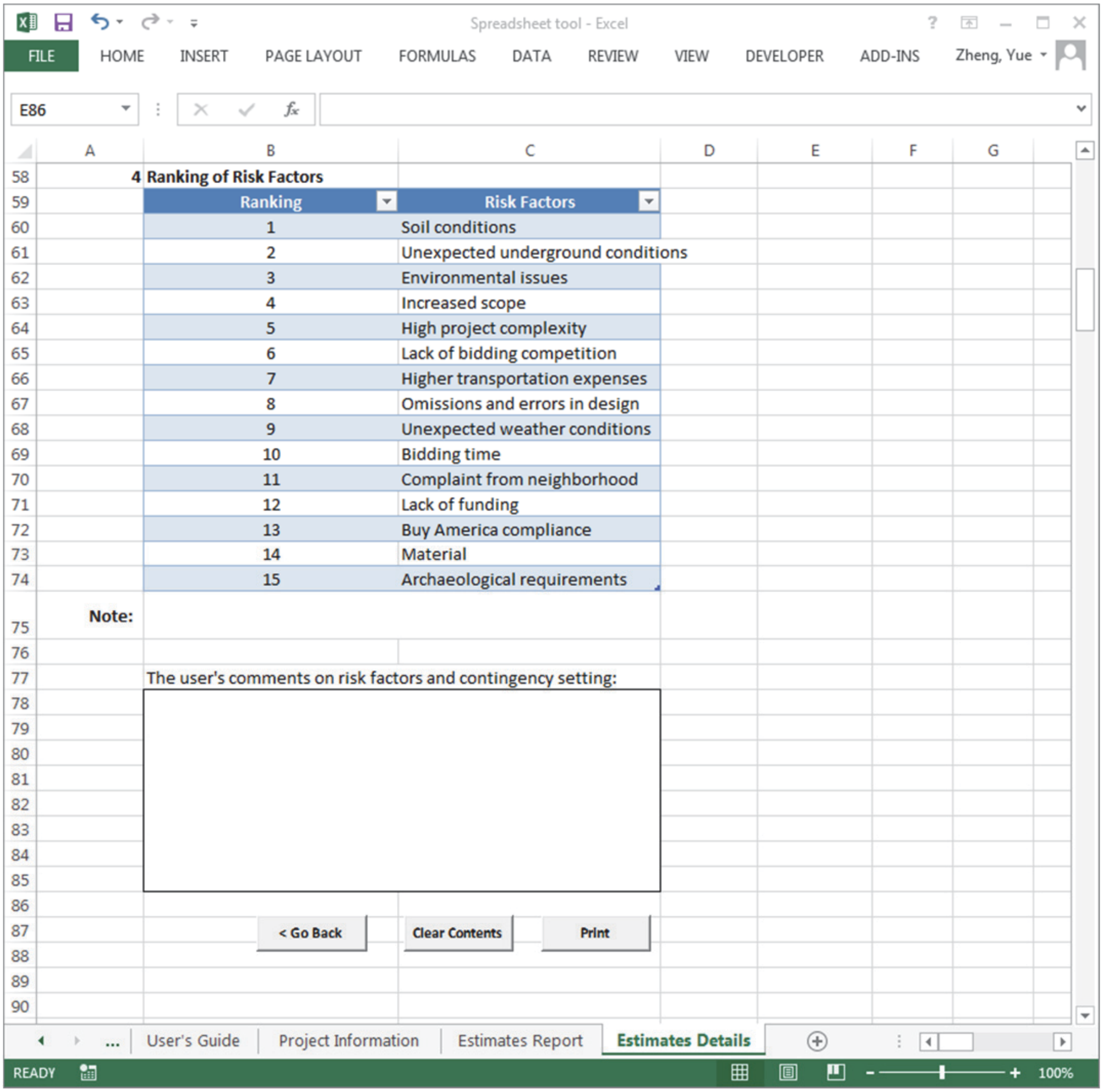


Figure 20 (D) Screen capture of the Cost Estimating Prototype Tool—Estimates Details (continued).

Steps of Cost Estimation Practice and Cost Estimation Management

The steps of cost estimation practice and management were developed based on guidance from *NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction* (Anderson et al. 2007) and the Minnesota Department of Transportation *Cost Estimation and Cost Management: Technical Reference Manual* (Minnesota Department of Transportation 2008). Although both guidebooks are focused on highway cost estimation and cost estimation management, the descriptions for each step are generic and applicable to facilitating the development of rural and small urban area transit facility estimates. The five-step estimating process developed by Anderson et al. (2007) is provided as follows:

1. Determine estimate basis (e.g., project scope, location, unique characteristics),

2. Prepare base estimate (techniques and tools, historical database, adjustment factors),
3. Determine risk and set contingency (uncertainty in estimate basis and base estimate to determine the dollar amount of cost contingency),
4. Review and approve estimate (structured approach to verify completeness, estimate data used, documentation, accountability for estimate), and
5. Determine estimate communication approach (convey basis, assumptions, uncertainty).

Appendix H contains descriptions of each cost estimation step. The cost estimating prototype tool in the research can facilitate all these estimating steps. For example, a transit agency, referred to as "ABC" in this research, needs to construct a transit complex, including administration and maintenance facilities. A conceptual estimate of this project could be prepared by following this five-step estimating process.

First, when determining the estimate basis of this project, the transit manager should determine and document the project concept definition (e.g., project size, location, and descriptions of key works) and site characteristics. After determining the estimate basis, the transit manager should input the following key information into the estimating prototype tool: project size (e.g., 6000 ft^2), location (e.g., Butler, Pennsylvania), facilities function and features (e.g., administration and maintenance), and site characteristics (e.g., the site used to be an old depot, and therefore the underground conditions could increase construction cost).

Second, in order to prepare the base estimate, the transit manager should select an appropriate estimating approach and a tool supporting conceptual cost estimating. Assumptions, such as for the inflation rate, should be made in this step. In this case, the transit manager selects the cost estimating prototype tool developed in this research and inputs assumptions into the prototype tool, such as the estimated midpoint of design year (e.g., 2015), the estimated midpoint of construction year (e.g., 2016), and the inflation rate (e.g., 3.0%).

Third, project risks should be determined in order to set contingency. The transit manager should identify potential risks, such as unexpected underground and weather conditions, and document these in the prototype tool. For a low-complexity project, percentages of construction cost are used to estimate the range of contingency. The transit manager defines contingency as follows: lower boundary (e.g., 10%), most likely contingency percentage (e.g., 15%), and upper boundary (e.g., 20%). Clicking the Calculate and Continue button, the estimate report will be provided. The screen captures of the Project Information section are shown in Figure 21.

Fourth, the appropriateness and completeness of the estimate should be reviewed and verified. In this instance, the transit manager should review and check the Estimates Report and calculation details presented by the prototype tool. Screen captures of the Estimates Report and Estimates Details are shown in Figure 22 and Figure 23.

Last, in order to help communicate information about the estimates, transit managers can print the estimate report and estimate details, which convey estimate basis, assumptions, and project risks.

Limitations of the Research

The cost estimating database and prototype tool only support conceptual estimating during the schematic development phase since this is the level of historical cost data collected. Both the cost estimating database and prototype tool were constructed based on the actual historical cost data available for rural and small urban area transit facilities. The following factors may be related to the lack of data:

- A limited number of transit facilities were constructed in the rural and small urban areas in the last 5 years.
- The majority of potential survey participants in the contacts database provided by the RTAP are state DOT personnel and transit managers. Some may lack the cost estimating knowledge to complete the survey, or the data simply are not kept.
- Respondents have difficulty in accessing projects' design and construction cost data.
- The public transit programs of state DOTs and transit agencies have experienced staff shortages, and therefore DOT personnel and transit managers did not have time to complete the online survey.

However, the database of relevant cost elements and the estimating prototype tool can be improved by performing further data collection on a larger scale and with an extended amount of time. Design consultants and contractors could be another source of historical cost data.

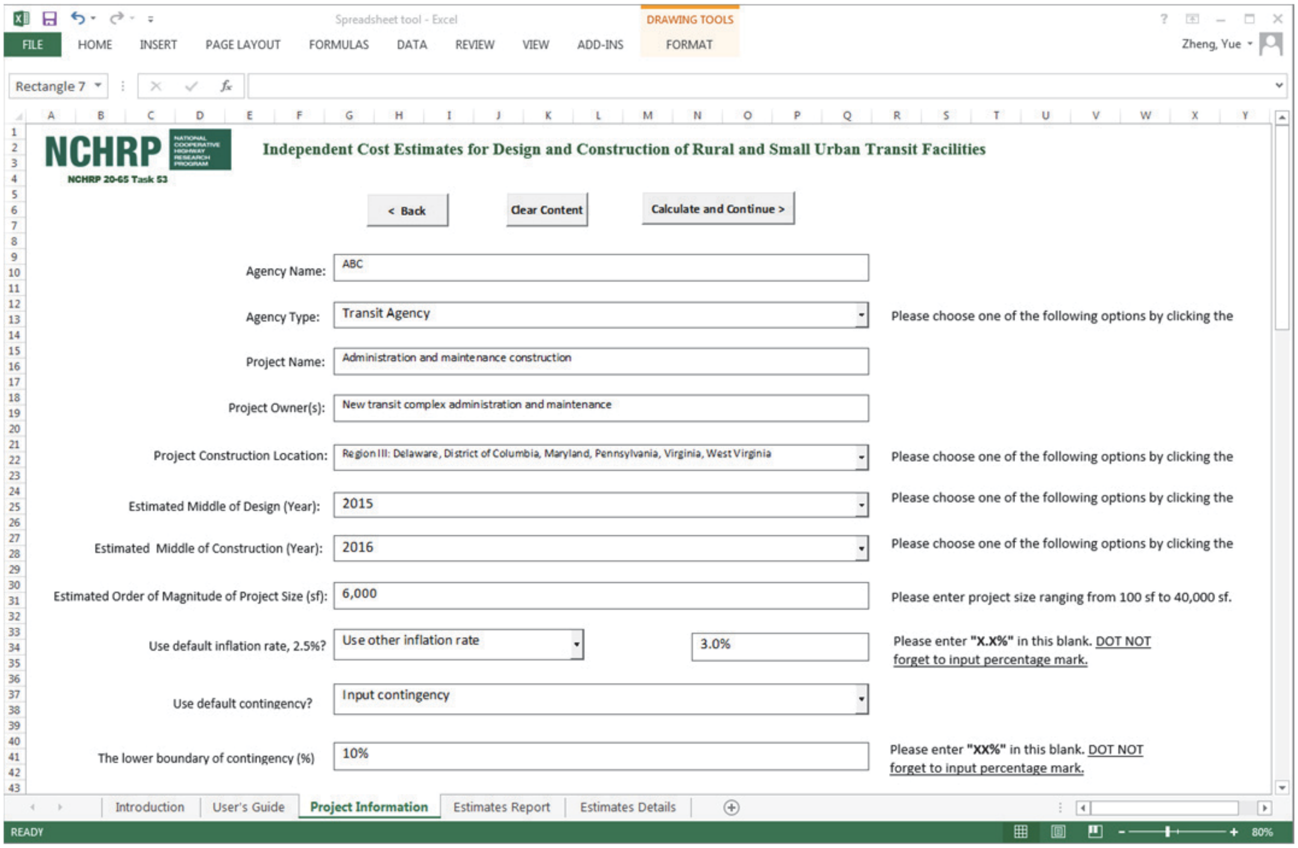


Figure 21 (A) Screen capture of ABC Project—Project Information.

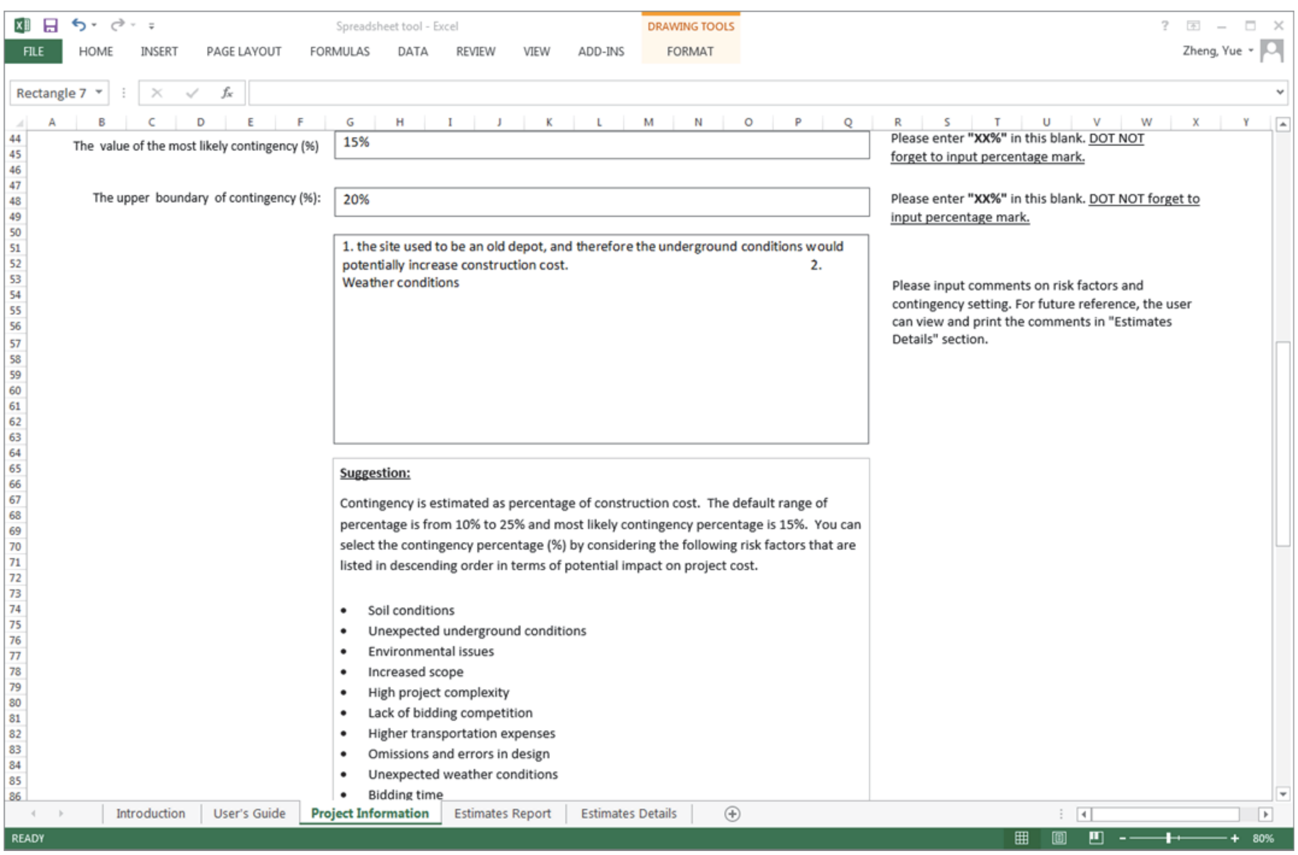


Figure 21 (B) Screen capture of ABC Project—Project Information (continued).

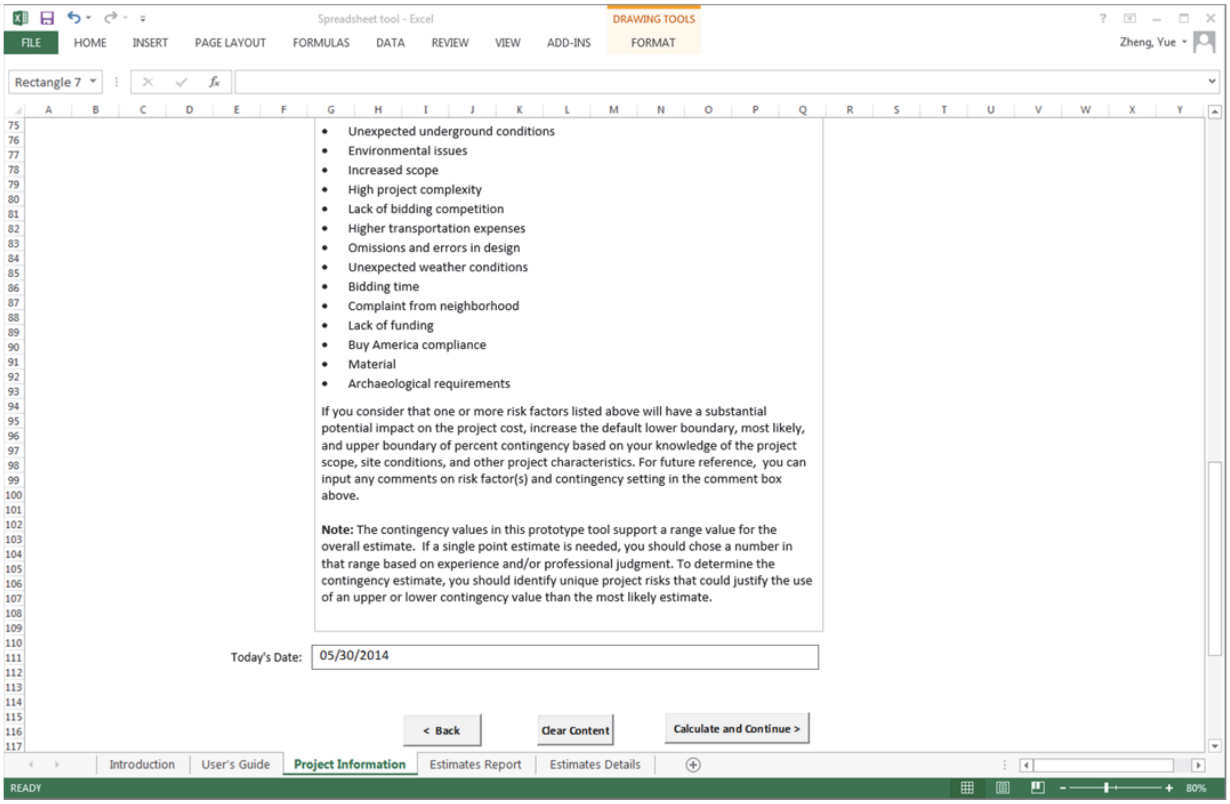


Figure 21 (C) Screen capture of ABC Project—Project Information (continued).

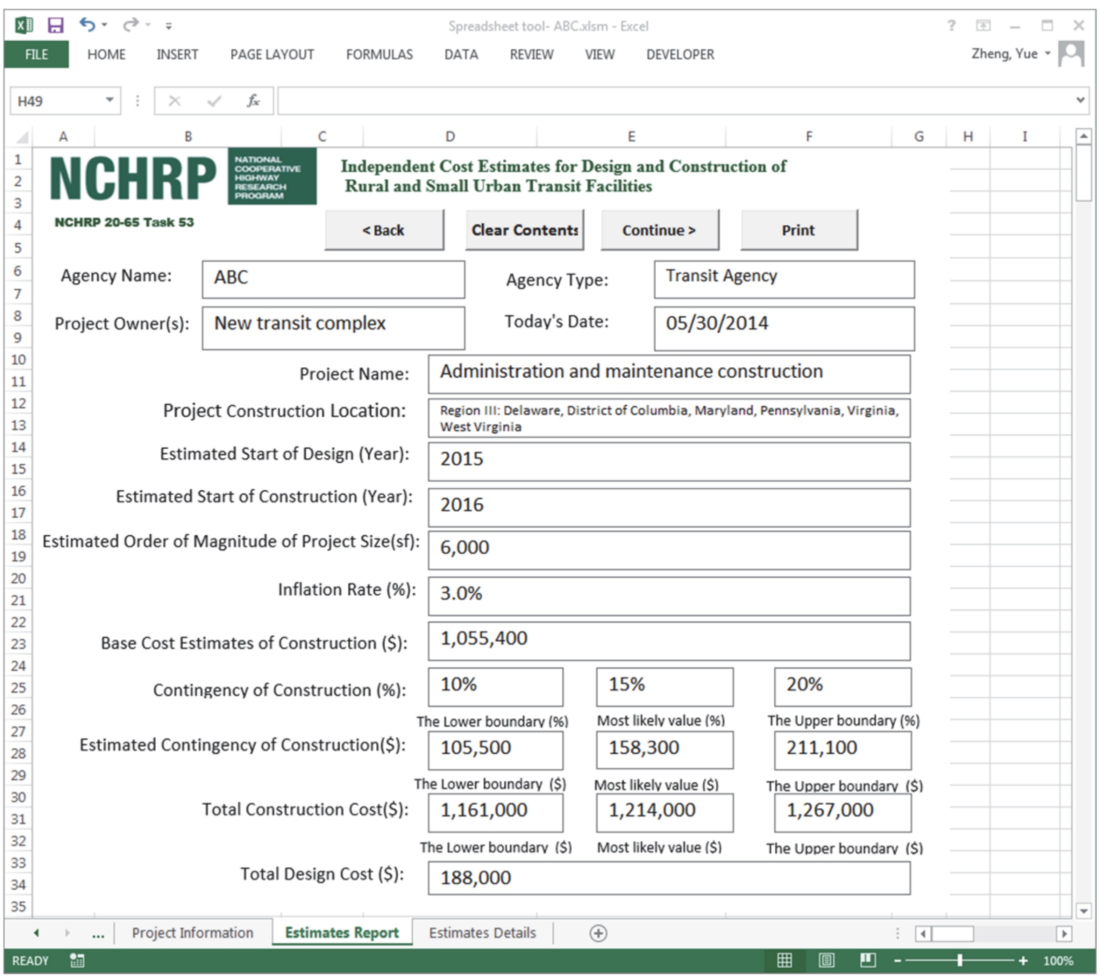
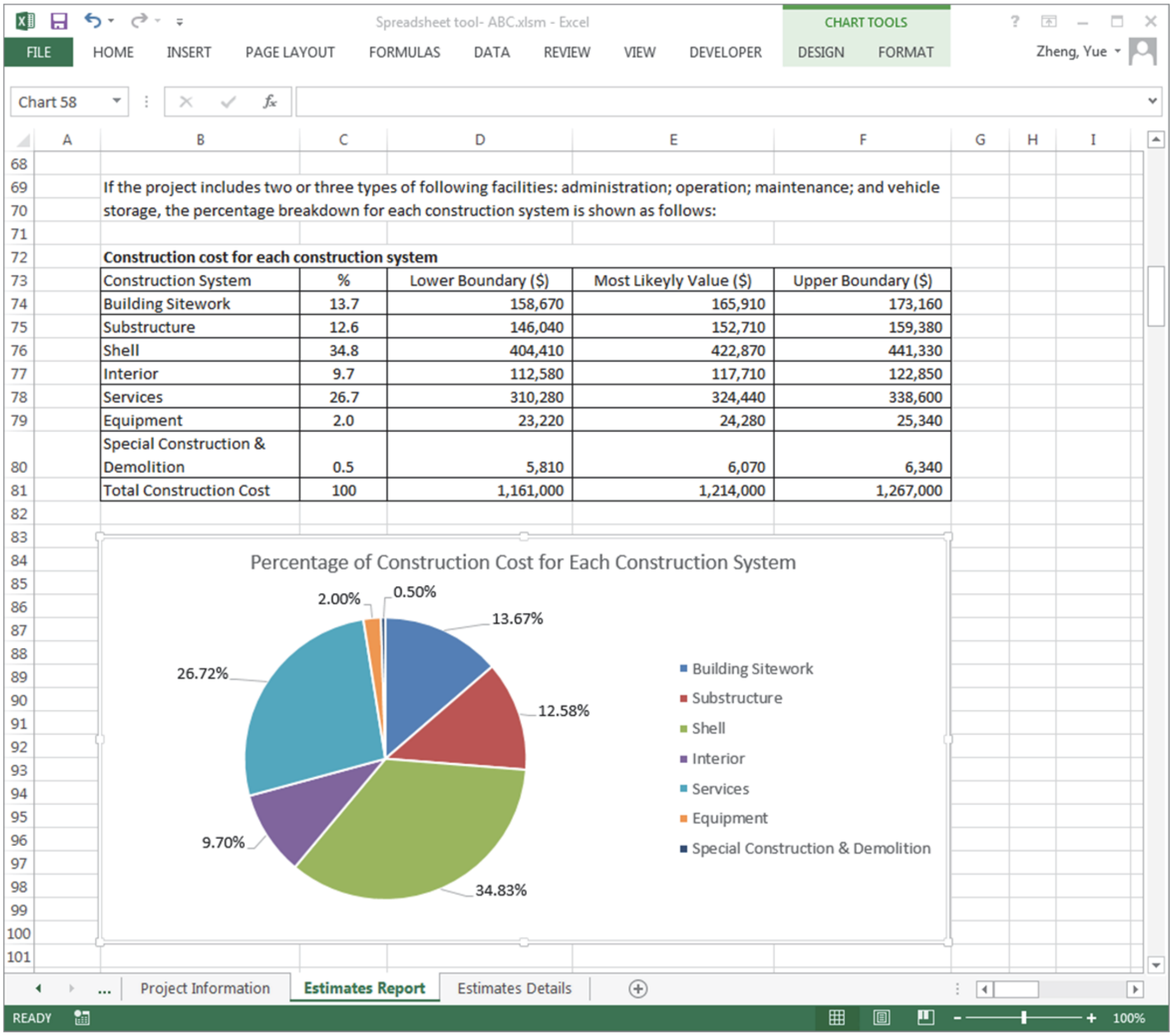


Figure 22 (A) Screen capture of ABC Project—Estimates Report (continued).



If the project includes two or three types of following facilities: administration; operation; maintenance; and vehicle storage, the percentage breakdown for each construction system is shown as follows:

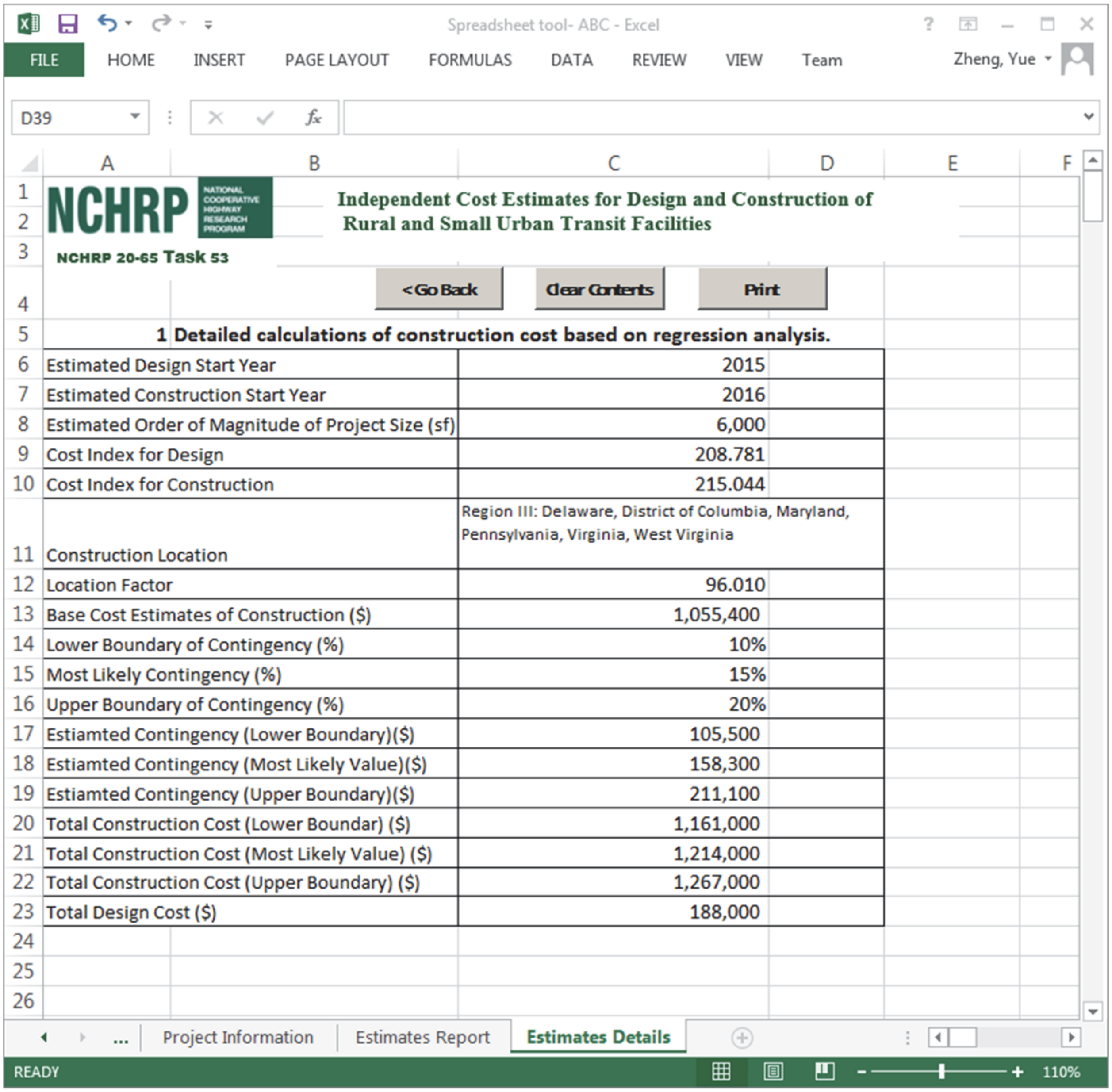
Construction cost for each construction system

Construction System	%	Lower Boundary ($)	Most Likeyly Value ($)	Upper Boundary ($)
Building Sitework	13.7	158,670	165,910	173,160
Substructure	12.6	146,040	152,710	159,380
Shell	34.8	404,410	422,870	441,330
Interior	9.7	112,580	117,710	122,850
Services	26.7	310,280	324,440	338,600
Equipment	2.0	23,220	24,280	25,340
Special Construction & Demolition	0.5	5,810	6,070	6,340
Total Construction Cost	100	1,161,000	1,214,000	1,267,000

Figure 22 (B) Screen capture of ABC Project—Estimates Report (continued).

CHAPTER 7 GUIDELINES FOR REVIEWING COST ESTIMATES

This chapter covers guidelines for reviewing cost estimates from an owner's perspective. The basis of the guidelines for rural and small urban area transit facilities was tailored from previous research: NCHRP Project 20-07/Task 278, "Production of the New AASHTO Guide to Estimating" and Task 308, "Completion of the New AASHTO *A Practical Guide to Estimating*"; *NCHRP Report 574: Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction;* and the Minnesota Department of Transportation's *Cost Estimation and Cost Management: Technical Reference Manual* (Minnesota Department of Transportation 2008). The cost estimating processes developed in these research projects have a history of success in preparing consistent, reliable, and accurate estimates at any phase in the project development process. Since the process is generic, it is applicable to development of rural and small urban area transit facilities as well. Moreover, reviewing estimates by following guidelines provided in this chapter will ensure the quality of estimates. The review guidance follows the generic cost estimate development process in Figure 24.



1 Detailed calculations of construction cost based on regression analysis.	
Estimated Design Start Year	2015
Estimated Construction Start Year	2016
Estimated Order of Magnitude of Project Size (sf)	6,000
Cost Index for Design	208.781
Cost Index for Construction	215.044
Construction Location	Region III: Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia
Location Factor	96.010
Base Cost Estimates of Construction ($)	1,055,400
Lower Boundary of Contingency (%)	10%
Most Likely Contingency (%)	15%
Upper Boundary of Contingency (%)	20%
Estiamted Contingency (Lower Boundary)($)	105,500
Estiamted Contingency (Most Likely Value)($)	158,300
Estiamted Contingency (Upper Boundary)($)	211,100
Total Construction Cost (Lower Boundar) ($)	1,161,000
Total Construction Cost (Most Likely Value) ($)	1,214,000
Total Construction Cost (Upper Boundary) ($)	1,267,000
Total Design Cost ($)	188,000

Figure 23 Screen capture of ABC Project—Estimates Details.

Process of Reviewing Cost Estimates

A cost estimating reviewer should answer the following five general questions:

1. Did the project meet all regulations of the FTA? For additional information and regulations of the FTA, refer to Circular C 4220.1F: Third Party Contracting Guidance (Federal Transit Administration 2013) and Project and Construction Management Guidelines (Federal Transit Administration 2011)
2. Did the estimator clearly follow a structured cost estimating process, such as that depicted in terms of the flowchart in Figure 24?
3. Were all key inputs taken into consideration and clearly documented by the estimator (e.g., historical data, market conditions, cost estimating techniques and tools, the macro environment, and information from third parties)?
4. Were assumptions determined and documented clearly by the estimator?

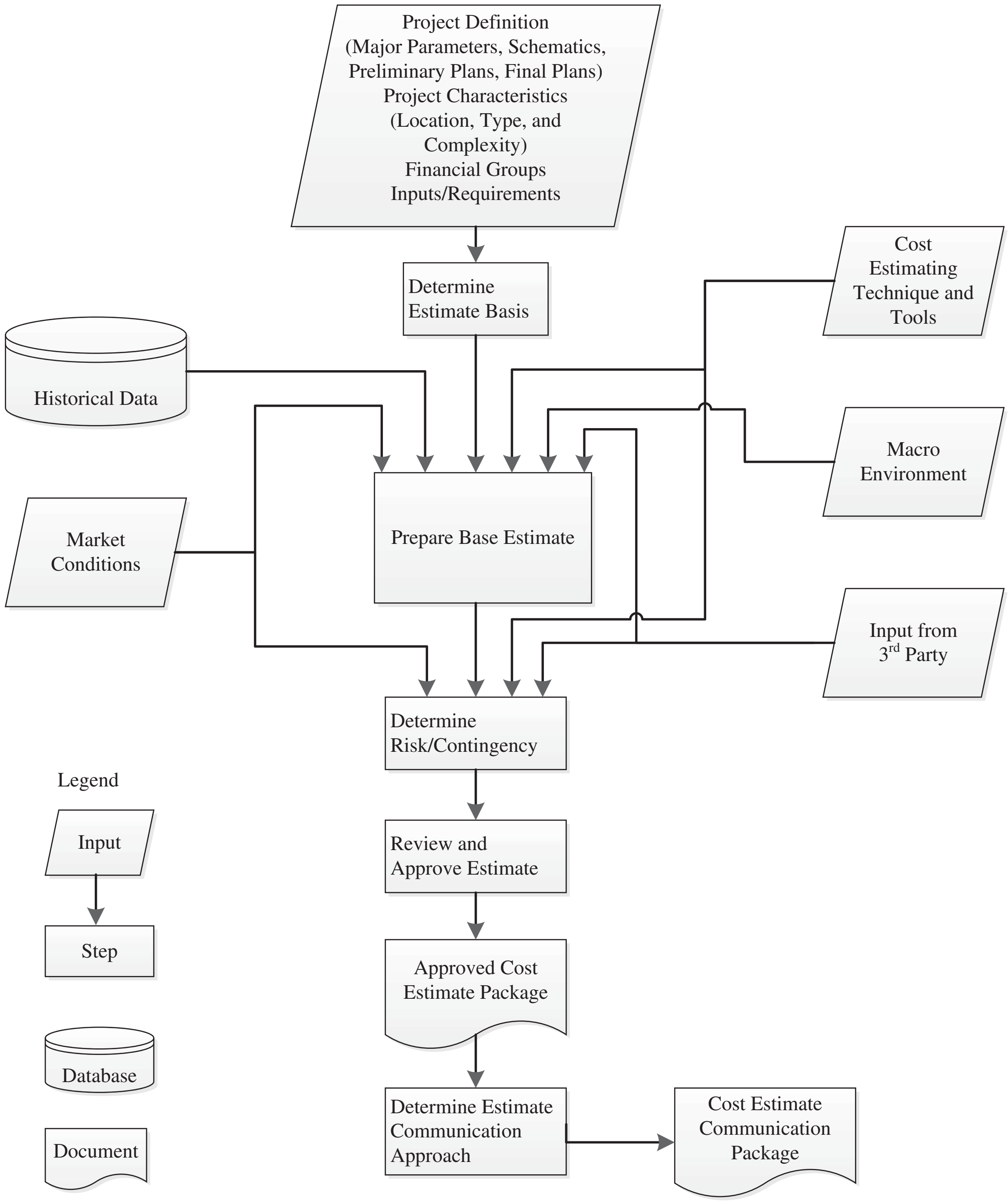


Figure 24 Cost estimating process derived from the Practical Guide to Cost Estimating (American Association of State Highway and Transportation Officials 2013).

5. Is there a project cost estimate file available that contains all the information relevant to preparing a project cost estimate (questions 1 to 3)?

Determine Estimate Basis

Reviewing the estimate basis serves the purpose of ensuring that all information required to prepare a cost estimate is collected and clearly documented. This step includes the following aspects:

- Is the scope of the project clearly defined, including what is included in the scope and what is not included in the scope?
- Has the estimator visited the future construction site to determine the existing conditions and any potential site access issues?
- Is the technical scope for the estimate consistent with the regulatory requirements and constraints (e.g., permit conditions, regulations)?
- Has the estimator asked for, and been provided with, clarifications from the design team, local stakeholders, or appropriate permitting agencies, where necessary?
- Has an estimate file (or report) been prepared to document the estimate basis (e.g., drawing numbers and dates, specifications, quotes)?
- Has a list of key assumptions, clarifications, and exclusions been prepared to document what is not yet designed or known about the project?

Prepare Base Estimate

When reviewing the most likely cost estimate (base estimate) without a contingency, the following should be considered:

- Were appropriate estimating methods used in relation to the available scope information, historical cost data, and other references used by the estimator (e.g., conceptual, bid-based, cost-based, and risk-based estimating methods)?
- Were assumptions and calculations documented clearly?
- Were estimate components identified, measured, and quantified correctly by the estimator?
- Are the categories summarized in an estimating tool (e.g., spreadsheets) consistent with the components of the total project cost estimate? Are the calculations in the backup correct?
- Were the estimating assumptions and base cost estimate summary and details clearly documented?

Determine Risk and Contingency

In order to review risks and contingency determined by the estimator, the reviewer should consider the following:

- What is the contract type for the project? According to the FTA, typical contract types include firm fixed-price and cost reimbursement contracts. However, cost plus a percentage of cost and percentage of construction cost contracts are prohibited. Time and materials contracts can be used only when no other contract type is suitable and a ceiling price is confirmed.
- Does the estimate explicitly identify a contingency amount?
- Does the estimate file (or report) clearly justify the basis of the contingency estimate?
- Is there a list of key assumptions, clarifications, and exclusions that address project unknowns and project risks (see also Determine Estimate Basis)?
- Has the estimate been reviewed for any contingency buried in line items or not explicitly identified?
- Has the final contingency estimate been compared to other contingency estimates for similar projects?
- Is lack of bidding competition a potential risk factor in the project? For example, when a single proposal is received, which is considered as one without price competition, the estimated contingency is recommended to be increased.

Review and Approve Estimate

Before an estimate is released to both internal and external project stakeholders, it should be reviewed and approved. This step includes the following considerations:

- Does the estimate cover the entire project scope, as known at the time of the estimate?
- Are cost estimating methods and historical cost data applications consistent with the scope definition?
- Are the estimate basis, assumptions, allowances, unknowns, contingencies, and changes from previous estimates documented in the final estimate package in a clear and concise manner?

- Were the estimating documents in the project estimate file reviewed?
- Has the cost estimate been approved by the appropriate level of management?

Determine Estimate Communication Approach

This step ensures that the cost estimates are a vehicle for succinctly and clearly conveying key project information to both internal and external project stakeholders. The following questions should be considered:

- Does the estimating package include major features of the project, specialty features, and features that have been considered?
- Were key assumptions, allowances, unknowns, and contingencies identified and documented?
- Are the estimating spreadsheets and diagrams in the estimating package comprehensive and clearly depicting the cost estimate for the project?

CHAPTER 8 CONCLUSIONS

This chapter summarizes the conclusions that were drawn from this study and provides recommendations for future research.

Conclusions

This research included a literature review, telephone interviews, and an online survey. A cost estimating database was constructed based on historical cost data collected through the survey. Analysis of historical cost data was the basis for development of the cost estimating prototype tool. The general conclusions are:

- Project design and construction costs depend on various factors, such as facility types, project size, location, and facility features.
- Many construction projects for rural and small urban area transit facilities were suspended or delayed due to lack of funding.
- Most transit projects in rural and small urban areas include more than one type of facility.
- State DOTs and transit agencies rely on estimates prepared by consultants. State DOTs hire consultants to perform independent cost estimate reviews.
- Both design and construction costs are estimated based on similar projects. Regression functions of design and construction costs were obtained through regression analysis, and the functions were used in the cost estimating prototype tool to predict future design and construction costs at the conceptual estimating phase.
- Risk factors were identified through telephone interviews, and the frequency of the risk factors was obtained from the online survey.
- In order to address project risks, contingency is estimated as a percentage of construction cost. The ranges of contingency percentage given by the interviewees and survey results provided a reference for determining the default contingency range for the cost estimating prototype tool.

Recommendations for Future Research

A cost estimating database and a prototype tool were developed based on actual historical cost data collected via the online surveys. Further research should be conducted in order to capture additional data through the following approaches.

First, it is necessary to target a greater number of practitioners with cost estimating expertise who are involved in rural and small urban area transit facility projects, especially design consultants and contractors that may provide historical data.

Second, as an alternative to collecting cost data through a survey, a Delphi process can be performed. The candidates of the Delphi study can be personnel at state DOTs who are in charge of funding distribution of rural capital programs, transit managers having knowledge of cost estimating, and consultants having experience in design and construction of transit facilities in rural and small urban areas. In order to ensure consistency in sample size, it is better that all the experts can respond to each round of the Delphi surveys.

Third, through the online survey, it was found that most rural and small urban area transit projects were combinations of many types of facilities, such as those for administration, operations, maintenance, and vehicle storage. Therefore, in the future data collection process, it may be better to ask the survey participants to provide size and cost for each type of facilities in one project so that an estimating tool can be developed to support estimates for each type of facilities.

Fourth, the survey data were incomplete concerning park-and-ride facilities, sheltered bus stops, unsheltered bus stops, and sign-only bus stops. Efforts in collecting data on the costs of those types of facilities should be made in the future.

Last, the cost and schedule impacts of each risk factor should be requested in the survey so that risk factors can be quantified; risk analysis and management for rural and small urban area transit facilities can thereby be better structured.

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APPENDIX A PROCESS FOR FACILITY CONSTRUCTION (ODOT, RURAL TRANSIT PROGRAM)

Planning Phase: Review Rural Transit Facility Prototype

1. Develop conceptual plans
2. Prepare square footage cost estimate
3. Site decisions–site needs
4. Environmental considerations

Step 1

A. Program project on a 4-year capital and operating (C&O) plan:
   1. Phase 1: architectural and engineering services, and
   2. Phase 2: construction

Costs at this time will be from tentative estimates based on similar projects and consultation with city/county engineering staff, and so forth.

B. Complete a feasibility study to document the need for the facility and to conduct site selection, and include preliminary drawings and environmental work. To the extent feasible, prepare preliminary design sketches and provide pictures or schematics of existing facilities with estimated costs.

Step 2

A. Apply for funding
   1. Submit application
   2. Complete the scoping process
   3. Following scoping process, application approval, and contract approval, for construction projects, proceed with Phase 1 work outlined in the following
      a. Phase 1: architectural and engineering services
         (1) Conduct qualifications-based selection (QBS) process (in accordance with Brooks Act)
         (2) Develop QBS and obtain ODOT concurrence
         (3) Select an architecture/engineering (A/E) firm
         (4) Negotiate contract
         (5) Conduct A/E work:
            (a) Preliminary design
            (b) Site selection and environmental work
               5-b-1. Submit environmental package to ODOT for submission to FTA
               5-b-2. Following FTA concurrence, proceed with site development. If FTA does not concur, additional environmental work will need to be conducted or alternative site selected.
         (6) Site development (construction only)
         (7) Prepare construction bid documents
         (8) Submit periodic invoices to ODOT

B. Construction management oversight (optional in Phase 1–can be done as part of the overall construction bid if desired)
   1. Conduct selection process
   2. Development bid/proposal for project oversight services and obtain ODOT concurrence
      a. Select project manager
      b. Negotiate contract

Step 3

A. Apply for funding for Phase 2: construction
   1. Submit application
   2. Following approval and contract execution with ODOT, proceed with next steps

B. Bid construction project
   1. Negotiate contract
   2. Monitor construction (construction manager)

C. Perform project oversight (construction manager)
   1. Perform regular site visits
   2. Oversee general contractor (if separate from construction manager) and subcontractors
   3. Check site work with specifications
   4. Negotiate any necessary change order
   5. Report progress and any problems to grantee
   6. Approve and/or submit invoices to ODOT

Step 4

Continue to monitor the project. Although ODOT will also monitor the project, it is the grantee's responsibility to provide project oversight and ongoing monitoring.

Notes

- Section 5311 grantees can choose to conduct the A/E portion locally without Section 5311 funding. They must still follow the Brooks Act requirements as well as FTA requirements for conducting the environmental assessment and so forth, and ODOT must still review and approve the selection process and contracts.
- As noted previously, construction oversight can be bid separately after the A/E work is performed and either prior to or concurrent with the construction bid process or as part of the overall construction bid.

[Note: Appendices B through E are unpublished.]

APPENDIX F LOCATION ADJUSTMENT FACTOR

The RS Means city index has a base value of 100.0, representing a 30-U.S. city average. The location adjustment factor is determined by dividing the "City Index" column value (Column 4 in Table 10) by 100.0. For example, the location factor for Bridgeport, Connecticut, would be 111.3/100.0, or 1.113.

APPENDIX G TOOL REVIEW PROTOCOL

Following is the text of the tool review protocol for NCHRP Project 20-65/Task 53.

As part of NCHRP Project 20-65, Task 53, this research focuses on the development of independent cost estimates for the design and construction of rural and small urban area transit facilities. The work is being conducted by the Texas A&M Transportation Institute (TTI). The research products include a database of historical cost elements and a cost estimating tool. The purpose of the cost estimating tool is to assist state transportation agencies (STAs) with the distribution and management of funding for rural and small urban area facilities. It should also assist transit operators when they apply for funds from the Rural Transit Assistance Program. This cost estimating prototype tool was developed based on the limited amount of valid historical cost data currently available.

The research team thanks you for your previous participation in the interview and/or online survey. Now the research team is inviting you to review the prototype tool by estimating a project and provide your suggestions on revising the tool by answering the following questions.

1. Is it easy to navigate the tool by following the instructions provided? If you have any difficulty, please explain the issue and provide your suggestions for improvement.
2. Do you think the User's Guide is self-explanatory and comprehensive? Did you have any difficulty in understanding how to set the following variables?
   - Inflation factor
   - Location adjustment factor
   - Contingency (%)

   Do you think the default values are appropriate? Please list any difficulties you experienced.
3. Did you have any difficulty in completing the project information section? Do you think the suggestions and instructions concerning the contingency setting are helpful?
4. Do you think the estimates report clearly shows the base construction estimates, contingency range, total construction cost, design cost, and construction cost for each construction system? If you have any suggestions, please list them here.
5. Do you think the Estimates Details section is helpful for understanding the adjustment factors and calculations of the construction and design costs? If there was any cause for

(*continued on page 55*)

Table 10 Location adjustment factor.

	City Name	Population*	City Index
Region I Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont			
Connecticut	Bridgeport	144,229	111.3
	New London	27,620	108.9
	Waterbury	110,366	111
	Norwalk	85,603	114.5
Maine	Portland	66,194	97.1
	Rockland	7,297	91.8
	Waterville	15,722	89.7
Massachusetts	Boston	617,594	118.9
	Fall River	88,857	114
	Springfield	153,060	106.8
	Framingham	68,318	114.2
New Hampshire	Manchester	109,565	98.8
	Nashua	86,494	98.1
	Concord	42,695	97.7
	Littleton	5,928	88.9
Rhode Island	Newport	24,672	108.1
	Providence	182,911	109.5
Vermont	Burlington	42,417	95.1
	Rutland	16,495	93.8
	Montpelier	7,855	93.5
Number of cities	**20**	**Average of city indices**	**103.085**
Region II New Jersey, New York, Puerto Rico, Virgin Islands			
New Jersey	Newark	277,140	114.7
	Atlantic City	39,558	110.9
	Elizabeth	124,969	112.7
	Trenton	124,969	112.7
	New Brunswick	55,181	113.1
	Jersey City	247,597	112.6
	Paterson	146,199	113.3
	Vineland	60,724	110.5
	Hackensack	43,010	112.5
	Summit	21,457	112.3
New York	Albany	97,660	102
	New York	8,244,910	133.1
	Jamestown	31,020	93.1
	Elmira	29,204	97.2
	Mount Vernon	67,780	117.8
	Glens Falls	14,728	94.4
	Syracuse	145,151	98.8
	Watertown	27,423	96.2
	Poughkeepsie	32,790	113
Puerto Rico	Puerto Rico	3,725,789	80.4
Number of cities	**20**	**Average of city indices**	**107.565**

Table 10 (Continued)

	City Name	Population*	City Index
Region III Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia			
Delaware	Wilmington	71,305	104.5
	Newark	31,618	104.2
	Dover	36,560	104.6
District of Columbia	N/A		
Maryland	Baltimore	619,493	93.2
	Cumberland	20,739	90.9
	Salisbury	30,484	83.4
	Elkton	15,443	90
Pennsylvania	Philadelphia	1,526,006	115.4
	Pittsburgh	305,704	102.9
	Reading	88,082	100.1
	York	43,718	97.9
Virginia	Norfolk	245,782	87.4
	Portsmouth	96,470	85.3
	Richmond	210,309	87.7
	Winchester	26,881	92.3
	Fairfax	23,461	93.7
West Virginia	Charleston	51,400	97.9
	Huntington	49,138	99.2
	Martinsburg	17,227	93.9
	Romney	1,848	95.7
Number of cities	**20**	**Average of city indices**	**96.01**
Region IV Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee			
Alabama	Anniston	23,106	82.5
	Mobile	195,111	84.8
	Selma	20,756	77.2
Florida	Jacksonville	823,316	85
	Pensacola	51,923	84.8
	Tampa	335,709	91.1
Georgia	Atlanta	443,775	88.2
	Columbus	197,872	84.6
	Statesboro	29,779	80
Kentucky	Louisville	597,337	92.5
	Somerset	11,196	88.5
Mississippi	Columbus	23,640	79.6
	Jackson	173,514	84.4
North Carolina	Charlotte	731,424	82.3
	Rocky Mount	57,477	78.4
South Carolina	Columbia	130,591	80.8
	Aiken	29,627	86
Tennessee	Memphis	655,155	87.8

(continued on next page)

Table 10 (Continued)

	City Name	Population*	City Index
	Chattanooga	171,279	86.5
	Cookeville	31,010	81.5
Number of cities	**20**	**Average of city indices**	**84.325**
Region V			
Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin			
Illinois	Bloomington	76,610	103.8
	Kankakee	27,537	111.2
	Chicago	2,695,598	118.4
Indiana	Columbus	787,033	90.5
	Fort Wayne	253,691	89.9
	Washington	11,739	90.7
Michigan	Detroit	713,777	103.7
	Muskegon	38,401	92
	Jackson	33,534	96.6
Minnesota	Minneapolis	382,578	109.7
	St. Cloud	65,842	106.6
	Windom	4,646	95.2
	Mankato	39,309	99.9
Ohio	Columbus	787,033	95.6
	Lima	38,771	95
	Marion	36,837	90.9
Wisconsin	Madison	233,209	100.6
	Green Bay	104,057	98.9
	Lancaster	3,868	96.2
	Milwaukee	594,833	104.5
Number of cities	**20**	**Average of city indices**	**99.495**
Region VI			
Arkansas, Louisiana, New Mexico, Oklahoma, Texas			
Arkansas	Little Rock	193,524	83.7
	Fayetteville	76,899	75.7
	Hot Springs	35,193	77.1
	Harrison	12,943	76.2
Louisiana	New Orleans	343,829	88.3
	Lafayette	120,623	83.8
	Monroe	48,815	81
	Thibodaux	14,566	85
New Mexico	Albuquerque	555,417	88.5
	Farmington	45,854	88.7
	Socorro	9,051	87.4
	Tucumcari	5,363	88.6
Oklahoma	Oklahoma City	599,476	84.9
	Tulsa	391,906	82.9
	Woodward	12,051	83.1
	Ponca City	25,387	81.3
Texas	Houston	2,160,821	87.5
	Dallas	1,241,162	85.7
	Bryan	78,061	81.5
	Victoria	64,376	75
Number of cities	**20**	**Average of city indices**	**83.295**

Table 10 (Continued)

	City Name	Population*	City Index
Region VII Iowa, Kansas, Missouri, Nebraska			
Iowa	Des Moines	203,433	93.7
	Cedar Rapids	126,326	93.6
	Burlington	25,663	88.7
	Creston	7,834	89.4
	Sibley	2,798	80.9
Kansas	Wichita	385,577	86.4
	Kansas City	147,268	98.7
	Topeka	127,939	86.3
	Salina	48,045	87.2
	Hays	20,993	85.5
Missouri	St. Louis	319,294	103.7
	Kansas City	459,787	104.8
	Rolla	19,559	96.9
	Sikeston	16,318	95.1
	Joplin	50,150	92.3
Nebraska	Omaha	421,570	91.3
	Alliance	8,499	88.6
	Grand Island	49,989	90.7
	McCook	7,652	87.5
	Norfolk	24,332	90.3
Number of cities	**20**	**Average of city indices**	**91.58**
Region VIII Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming			
Colorado	Alamosa	8,780	90.6
	Denver	600,158	94
	Greeley	92,889	90.1
Montana	Great Falls	58,505	92.6
	Wolf Point	2,621	90.5
	Billings	106,954	92.2
	Helena	28,190	90.7
North Dakota	Fargo	105,549	88
	Jamestown	15,427	77.5
	Williston	14,716	82.6
South Dakota	Sioux Falls	153,888	82.9
	Watertown	21,482	78.4
	Mitchell	15,254	77.5
Utah	Salt Lake City	186,440	88
	Price	8,715	85.4
	Logan	48,174	87.6
Wyoming	Cheyenne	59,466	86.3
	Rawlins	9,259	87.2
	Wheatland	3,627	85
	Rock Springs	23,036	87.5

(*continued on next page*)

Table 10 (Continued)

	City Name	Population*	City Index
Number of cities	**20**	**Average of city indices**	**86.73**
Region IX			
Arizona, California, Hawaii, Nevada			
Arizona	Phoenix	1,445,632	89.5
	Show Low	10,660	88.8
	Tucson	520,116	88
	Kingman	28,068	87.4
	Flagstaff	65,870	89.4
California	Berkeley	112,580	117.2
	Stockton	291,707	108.6
	Los Angeles	3,792,621	108
	Oxnard	197,899	106.8
	Redding	89,861	110
	Salinas	150,441	110.5
	San Luis Obispo	45,119	105.5
Hawaii	Hilo	43,263	116.6
	Honolulu	390,738	119.1
	States & Poss. Guam	159,358	100.8
Nevada	Las Vegas	589,317	104.9
	Reno	227,511	97.3
	Carson City	55,439	97.3
	Elko	18,546	93.1
	Ely	4,288	101.3
Number of cities	**20**	**Average of city indices**	**102.005**
Region X			
Alaska, Idaho, Oregon, Washington			
Alaska	Anchorage	291,826	119.8
	Fairbanks	31,535	119.9
	Juneau	31,275	120.1
	Ketchikan	8,050	126.1
Idaho	Boise	205,671	91.5
	Coeur d'Alene	44,137	97.7
	Idaho Falls	56,813	89.6
	Lewiston	31,894	99.3
	Pocatello	54,255	91.7
Oregon	Bend	76,639	99.8
	Eugene	156,185	99.6
	Portland	583,776	100.1
	Vale	1,874	91.7
	Medford	74,907	99.4
Washington	Clarkston	7,229	92.8
	Olympia	46,478	101.1
	Seattle	608,660	104.3
	Tacoma	198,397	102
	Yakima	91,067	99.9
	Wenatchee	31,925	96.1
Number of cities	**20**	**Average of city indices**	**102.125**

* Population statistics (2010) were obtained from the list of cities in the United States at Wikipedia.com.

(*continued from page 49*)

confusion, please list your suggestions for correcting the situation.

6. If more actual cost data are captured and there is a more refined differentiation of types of facilities with the appropriate cost data, would the cost estimating tool be helpful for your agency?

☐ Yes
☐ No

Please explain the reasons.

APPENDIX H COST ESTIMATING PROCESS

Table 11 shows the five steps of the cost estimating process and their descriptions.

Table 11 Steps of the cost estimating process.

Cost Estimation Step	Description
Determine estimate basis	Document project type and scope, including: • Scope documents, • Drawings that are available (defining percent engineering and design completion), • Project design parameters, • Project complexity, • Unique project location characteristics, and • Disciplines required to prepare the cost estimate.
Prepare base estimate	Prepare estimate, including: • Documentation of estimate assumptions, types of cost data, and adjustments to cost data; • Application of appropriate estimation techniques, parameters, and cost data consistent with level-of-scope definition; • Coverage of all known project elements; • Coverage of all known project conditions; and • Checking of key ratios to ensure that estimates are consistent with past experience.
Determine risk and set contingency	Identify and quantify areas of uncertainty related to: • Project knowns and unknowns, • Potential risks associated with these uncertainties, and • Appropriate level of contingency congruent with project risks.
Review and approve estimate	Review estimate basis and assumptions, including: • Methods used to develop estimate parameters (e.g., quantities) and associated costs, • Completeness of estimate relative to the project scope, • Application of cost data, including project-specific adjustments, • Reconciliation of current estimates with the baseline estimate (explain differences), and • Preparation of an estimation file that compiles information and data used to prepare the project estimate. Approving estimates includes: • Review of current project scope and estimate basis, • Securing of approvals from appropriate management levels, • Approval of current estimates, including any changes from previous estimates, and • Release of estimate for its intended purpose and use.
Determine estimate communication approach	Communication approach is dependent upon the stakeholder who is receiving the information, but should take into consideration: • Mechanism for communicating the cost estimate for its intended purpose, • Level of uncertainty to be communicated in the estimate given the information upon which it is based, and • Mechanism to communicate estimate to external parties.

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