

**COST ESTIMATING DATABASE AND PROTOTYPE TOOL TO SUPPORT
DESIGN AND CONSTRUCTION OF RURAL AND SMALL URBAN TRANSIT
FACILITIES**

A Thesis

by

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ABSTRACT

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 thesis focused on cost estimating methods, database, and prototype tool development for design and construction of rural and small urban transit facilities that are usually small, numerous, and geographically dispersed. To address these issues, the National Cooperative Highway Research Program (NCHRP) funded a research team to provide guidance to state transit agencies in assisting their sub-recipients with preparing accurate design and construction cost estimates. This thesis was written according to the scope of the funded research project.

The main objectives of this study were to determine the distinct characteristics of rural and small urban transit facilities and to develop a cost database and a prototype tool to assist agencies with preparing conceptual estimates. Conducting a literature review and telephone interviews with experts in the transit facility industry improved the understanding of the estimating practices used in the rural and small urban transit facility industry. Unique characteristics and risk factors of those facilities were identified. A cost estimating database was constructed based on the historical cost data collected through online surveys. A cost estimating prototype tool was developed based on the findings obtained from the literature review, telephone interviews, and analysis of the cost

estimating database. Review of the prototype tool was then performed to ensure the tool's self-explanation, functionality, and user-friendliness. This thesis contributes to the transit facility industry by developing the first national database and prototype tool to support conceptual estimating for rural and small urban transit facilities. A research limitation of this research and recommendations for future research were explicitly described at the end of this thesis.

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CHAPTER I

INTRODUCTION

BACKGROUND

Rural and small urban transit facility projects are relatively small in scope and dollar value, numerous, and also 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 impacting cost (e.g., remote location or lack of competition).
- 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 “strategic focus” and “how to” focus. NCHRP Report 574 provides Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction. It 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 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 technical reference manual on cost estimating and cost management produced for the Minnesota Department of Transportation (Minnesota Department of Transportation Cost Estimation Improvement and Organizational Improvement for Project, Phases III and IV) describes the estimating procedures in detail.

Recent research specific to rural projects includes NCHRP Project 20-65 Task 40, “Construction Management Practices for Rural Projects.” The report 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 estimation of rural and small urban transit facilities. Many factors are the causes of 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. According to the number of passengers served, the passenger facilities may vary from unsheltered bus stops to transit terminals, or to transit centers. Third, the facilities

can involve new facilities but correspondingly the project maybe 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 to follow different cost management procedures. Section 5311, the Federal Transit Administration's (FTA) 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 database, it is difficult to prepare consistent, reliable, and accurate cost estimates for rural and small urban transit facility projects. Therefore, there is a need to study the unique characteristics of rural and small urban transit facility projects, establish a sound and structured historical cost database for design and construction, and develop a corresponding tool to facilitate the estimating process. The scope of this thesis covers these three issues.

PROBLEM STATEMENT

Most organizations that develop and deliver capital projects have a continuing program of projects. When a group of small projects are combined in a program, there will be a substantial percentage of the total construction budget. Overruns in many small

projects can lead to program overruns, and hence it can bring financial loss to the organizations. In the light of this reasoning, the agencies that manage the process of development and delivery of a group of rural and small urban transit facilities would have great potential risk in cost overruns. These overruns result because these facility projects are usually small in scope and on a limited budget, require various functions, and are geographically dispersed across the states. Consistent, reliable, and accurate cost estimates of these projects can provide organizations with dependable baseline for cost control to avoid overruns. However, good cost estimates depend on three main aspects, including the comprehensive knowledge of the nature of the project, a sound historical cost database, and an appropriate estimating methodology/tool, and neither of these aspects were addressed in previous research.

NCHRP Project 20-65 Task 40, “Construction Management Practices for Rural Projects,” one of the limited amount of rural transit facility studies, identified the general characteristics of rural transit projects and discussed challenges, strategies to overcome the barriers, and possible cost estimating resources. However, areas in the literature that are lacking include the following aspects:

- Distinguished characteristics and classifications of rural and small urban transit facilities.
- Current cost estimating practices used in the transit facility industry.
- Establishment of a nation-wide design and construction cost database.
- An appropriate cost estimating tool designed for rural and small urban transit facilities.

- Steps to incorporate the cost estimating tool into estimating processes for those facilities.

RESEARCH QUESTIONS

The research questions for this thesis included:

Characteristics and Classifications of Rural and Small Urban Transit Facilities

- Based on function types, how are the rural and small urban transit facilities classified? What are prevalent functional type or types?
- How do locations of rural and small urban projects impact the design and construction of these facilities? What are the differences between rural and small urban transit facilities?
- For each functional type, what is the typical project size in square foot (sf) either an average or a range? What is the typical project cost, 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 is 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, summarized estimating steps, etc.?
- How to use a historical cost estimating database developed in this research to support estimating design and construction costs of rural and small urban 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 objectives were to define the characteristics of rural and small urban transit facilities, develop an appropriate cost database of historical relevant cost elements, and create a prototype tool to support conceptual estimating process for these facilities. This research had the following three sub-objectives:

- Identify the current estimating practice used in the transit facility industry.
- Study the characteristics of available database 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 research objectives, this research included the following five tasks:

Task 1 Conduct a Review of Recently Designed and Constructed Rural and Small Urban Transit Facilities

The objective of Task 1 was to determine the characteristics of rural and small urban 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 Transit Facilities

The objective of Task 2 was to collect data and information concerning rural transit facilities to identify, at a minimum: 1) the size and type of the facility designed and constructed, 2) amenities provided, 3) location of the facility, 4) any unusual conditions, and 5) actual costs of design and construction. An online survey was used to collect this data 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 transit facilities. The historical cost data collected was input into a MS ExcelTM database and normalized to the national average in year of 2014 by using the “City Cost Index” and “Historical Cost Index” in the 2014 version R.S. Means Building Construction Cost Data manual.

Task 4 Develop a Cost Estimating Prototype Tool to Support Conceptual Estimating

The objective of Task 4 was to develop a cost estimating prototype tool using MS ExcelTM based on statistical analysis of the cost database developed in the previous task. A regression analysis was conducted to determine the relationship between cost and project size. This regression function was built in 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 Prepare the Master Thesis

The objective of Task 5 was to complete the master thesis following the guidelines of Texas A&M University. In the thesis, the research questions and objectives were fully addressed through the completion of research tasks stated above.

ORGANIZATION OF THE STUDY

This thesis consists of seven chapters. Chapter I sets the context of the research background along with the problem statement, research questions, research objectives, and research tasks. Chapter II focuses on the literature review concerning the characteristics of transit facility projects in rural and small urban areas, cost estimating databases and tools, and risk management practices. Chapter III describes the research methods, including telephone interview, online survey, survey data analysis, development of cost estimating database and prototype tool, and review of the prototype tool. Chapter IV provides information on the telephone interview protocol preparation, interview processes, and interview results. Chapter V discusses the survey protocols development, survey process, and results of data analysis. Chapter VI presents the development of cost estimating database, prototype tool, and estimating steps for rural and small urban transit facilities. A limitation of the prototype tool is also addressed at the end of the chapter. Finally, Chapter VII states study conclusions and discusses the recommendations for future research.

CHAPTER II

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 for the development of the cost estimating prototype tool. The key words used to search the literature included definitions of rural and small urban areas, transit facility functions and characteristics, cost estimating methodology, and risk identification tools and measurement methods.

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

- Transportation Research Board's Transportation Research Information Systems (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 agencies' websites.
- 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 (Dye Management Group 2001), a rural area is defined in two ways by the U.S. Department of Transportation. The first definition is an area with less than 5,000 people. The second definition is that rural is an area outside of metropolitan areas and the population is less 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 areas with a population of less than 50,000 people. Hallowell and colleagues' research identified cost estimating challenges, including the lack of historical data, remote locations, and less competition. To overcome these existing 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 the report 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 three major 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 percent of building a new facility of the same type. For the bus stops listed above, Texas A&M Transportation Institute developed per bus stop cost. For other types of facilities, the estimated per square foot cost is based on the Texas Department of Transportation Public Transportation Division's database of historical capital cost per square foot.

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

- **Level I:** As 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:** 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 change, brake repair, minor body work, as well as activities performed in Level I.
- **Level III:** Third level maintenance facility provides all kinds of vehicle maintenance, including engine and transmission rebuilding, testing, major body repairs, painting, as well as activities that can be conducted in Level I and 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 et al. 2002). The intercity transit industry is a private for-profit industry that offers scheduled passenger service and a number of 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 (Office of Transit, Ohio Department of Transportation 2012) was developed to assist rural transit services in compliance with all

applicable Federal and Ohio Department of Transportation (ODOT)'s requirements. The manual discusses the determination of the need for rural transit and rural transit facilities' implementation, use, maintenance, and operation. A series of documents were prepared by ODOT to support facility feasibility study, scoping process, acquisition, and the 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 six percentage 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 addresses 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 rural transit facility should be constructed in a simple and elegant but economic manner (Brown & Bills Architects 2012). In order to build sustainable facilities, the report requires general design and site selection of rural transit facilities meet Leadership in Energy and Environmental Design (LEED) rating of Silver or higher.

COST ESTIMATING

According to the recommended practice of Association for the Advancement of Cost Engineering International (AACEI), cost estimates for building construction can be

categorized into five classes (Bredehoeft, 2012). 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, and expected accuracy ranges are shown in Table 1.

Table 1 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%

Adapted from the Association for the Advancement of Cost Engineering International's AACEI Recommended Practice No. 56R-08: Cost Estimate Classification System, 2012.

¹ The +/- value represents typical percentage variation of actual cost from the cost estimate after application of contingency for given scope. The typically confidence level is 50%.

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 utilized.

Cost Estimating Databases

The R.S. Means Building Construction Cost Data manual is a primary and authoritative reference source of building cost information. R.S. Means manual tracks cost records from more than 900 cities in the U.S. 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. Projects data from locations across the United State are collected to develop the square foot cost at the national average level, and therefore, estimators' judgment and caution should be exercised when the square foot data is used. If more precision is needed, the latest edition of the R.S. Means Square Foot Costs manual would be a better reference. However, the square foot cost data in the manuals does not reflect characteristics of rural and small urban 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 is divided into the 50 divisions based on the 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 in different times. According to the R.S. Means (2014), “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.” Therefore, cost in one city can be adjusted to cost in another city and national average cost by using the following two equations:

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

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

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

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

City Cost Indexes provide data for a number of cities in the U.S. 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 (GIS). The test showed significant auto-correlation between proximity and City Cost Index values in R.S. Means, which confirmed the method suggested by R.S. Means. Regarding methods to estimate cost indexes of cities not sampled by R.S. Means, the researchers compared methods suggested by R.S. Means with two alternative methods. One is called conditional nearest neighbor (CNN) which 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 states regulations and policies on construction costs. The other is called State Average (ST AVG) which entails taking average of city indexes within a state and using the average as location adjustment factors 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 thesis.

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 and/or project parameters into estimates. However, the accuracy and validity of the estimates is limited since the cost estimating relationships are built on many assumptions. The estimate results are often prepared following the Construction Specification Institute (CSI)'s Unifomat, 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. The screen captures of the input page are shown in Figure 1. 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. The estimates of a dummy project are shown in Figure 2.

INPUT PARAMETER	VALUE
Case Description and Remarks (Optional):	<input type="text"/>
Usable Floor Area (s.f.):	<input type="text"/>
Average Floor to Floor Height (ft.):	<input type="text"/>
Number of Floors:	<input type="text"/>
Percent of Area as Office:	<input type="text"/>
Percent of Area as Wet Labs:	<input type="text"/>
Percent of Area as Dry Labs:	<input type="text"/>
Percent of Area Heated:	<input type="text"/>
Percent of Area Cooled:	<input type="text"/>
Number of Building Corners:	<input type="text"/>
Substructure Strength Index:	<input type="list" value="(0) ... 50 lbs/sf"/> <input type="list" value="(1) ... 96 lbs/sf"/> <input type="list" value="(2) ... 142 lbs/sf"/> <input type="list" value="(3) ... 188 lbs/sf"/>
Superstructure Strength Index:	<input type="list" value="(0) ... 50 lbs/sf"/> <input type="list" value="(1) ... 96 lbs/sf"/> <input type="list" value="(2) ... 142 lbs/sf"/> <input type="list" value="(3) ... 188 lbs/sf"/>
Exterior Finish Quality/Duty Index:	<input type="list" value="(1) ... Minimal Quality/Minimal Duty"/> <input type="list" value="(2) ... Below-Average Quality/Minimal Duty"/> <input type="list" value="(3) ... Average Quality/Light Duty (Means)"/> <input type="list" value="(4) ... Above-Average Quality/Light Duty"/>
Interior Finish Quality/Duty Index:	<input type="list" value="(1) ... Minimal Quality/Minimal Duty"/> <input type="list" value="(2) ... Below-Average Quality/Minimal Duty"/> <input type="list" value="(3) ... Average Quality/Light Duty (Means)"/> <input type="list" value="(4) ... Above-Average Quality/Light Duty"/>
Mechanical Services Quality/Duty Index:	<input type="list" value="(1) ... Minimal Quality/Minimal Duty"/> <input type="list" value="(2) ... Below-Average Quality/Minimal Duty"/> <input type="list" value="(3) ... Average Quality/Light Duty (Means)"/> <input type="list" value="(4) ... Above-Average Quality/Light Duty"/>
Electrical Services Quality/Duty Index:	<input type="list" value="(1) ... Minimal Quality/Minimal Duty"/> <input type="list" value="(2) ... Below-Average Quality/Minimal Duty"/> <input type="list" value="(3) ... Average Quality/Light Duty (Means)"/> <input type="list" value="(4) ... Above-Average Quality/Light Duty"/>
Escalation Factor (1995 US\$ Base):	<input type="text"/>
Location Factor:	<input type="list" value="Rural Area"/> <input type="list" value="US Average"/> <input type="list" value="Major or Innercity Urban"/>
Productivity Factor:	<input type="list" value="Good"/> <input type="list" value="Fair"/> <input type="list" value="Poor"/> <input type="list" value="Very Poor"/>
<input type="button" value="CALCULATE"/> <input type="button" value="RESET"/> <input type="button" value="EXAMPLE"/>	

Figure 1 Screen Capture of Input Page of Cost Estimating Model for Buildings

Results:			
CSI Account Description	Estimated Cost	Cost per Sq.Ft.	% of Total Cost
Foundations	\$18,062.00	\$1.81	1.28
Substructures	\$10,569.00	\$1.06	0.75
Superstructures	\$202,571.00	\$20.26	14.36
Exterior Closures	\$88,451.00	\$8.85	6.27
Roofing	\$23,433.00	\$2.34	1.66
Interior Construction	\$345,253.00	\$34.53	24.47
Elevators	\$68,156.00	\$6.82	4.83
Mechanical	\$310,083.00	\$31.01	21.98
Electrical	\$169,026.00	\$16.90	11.98
Specialties	\$24,712.00	\$2.47	1.75
Architect/Design Fee	\$150,486.00	\$15.05	10.67
TOTAL:	\$1,410,802.00	\$141.08	100

Input Parameters:					
Description:	Value:	Description:	Value:	Description:	Value:
Total Floor Area [s.f.]	10000	Ave. Floor Height [ft.]	12	Number of Floors	5
% as Office Space	80%	% as Wet Labs	5%	% as Dry Labs	5%
% Heated	95%	% Cooled	95%	Building Corners	4
Substructure Strength	5	Superstructure Strength	5	Exterior Finish	8
Interior Finish	8	Mechanical Services	8	Electrical Services	8
Escalation Factor	1	Location Factor	1.00	Productivity Factor	1.10

Figure 2 Screen Capture of Estimates Report of Cost Estimating Model for Buildings

DProfiler, developed by Beck Technology, integrates conceptual three dimension model with the process of cost estimating during planning and conceptual design phases. This has been widely used by architecture, engineering, and construction firms (Khemlani 2008). DProfiler uses R.S. Means cost database information that can be updated quarterly in order to capture the most current cost data if the users pay a maintenance and support program fee. When a user can 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 so the estimated cost can be adjusted to an appropriate local cost from the national average. The second is the building type. Using building type, the application automatically enables corresponding cost data to be applied to the components of the model. Figure 3 shows the screen capture for a new project. The user

can create, modify, and remove components based on the requirements of design. Figure 4 shows the modification of a model. When estimating the cost of each component, the user can either use the default R.S. Means cost data or input adjusted unit costs. The calculation formulas can also be modified based on the user's specific need. Figure 5 shows the screen capture of an estimate. The estimates report can be generated in the format of CSI MasterFormat or UniFormat. The model information can be exported into multiple formats, such as PDF, DPC, and XLS.

New Project Wizard

Welcome to DProfiler.

Before we start, let's collect a little bit of information about the project we are creating. If you don't know any of this information, you can always fill it in at a later point.

Project Information

Project Name: My Project

Client:

Address:

City: State:

Zip Code: RSMeans City Cost Index:

Country:

Web Page:

Unit Type: Imperial Currency: \$

Building Type: Office, 2-4 Story, Concrete Frame

Do not show me again.

Back Next Finish Cancel

Figure 3 Screen Capture of New Project Wizard

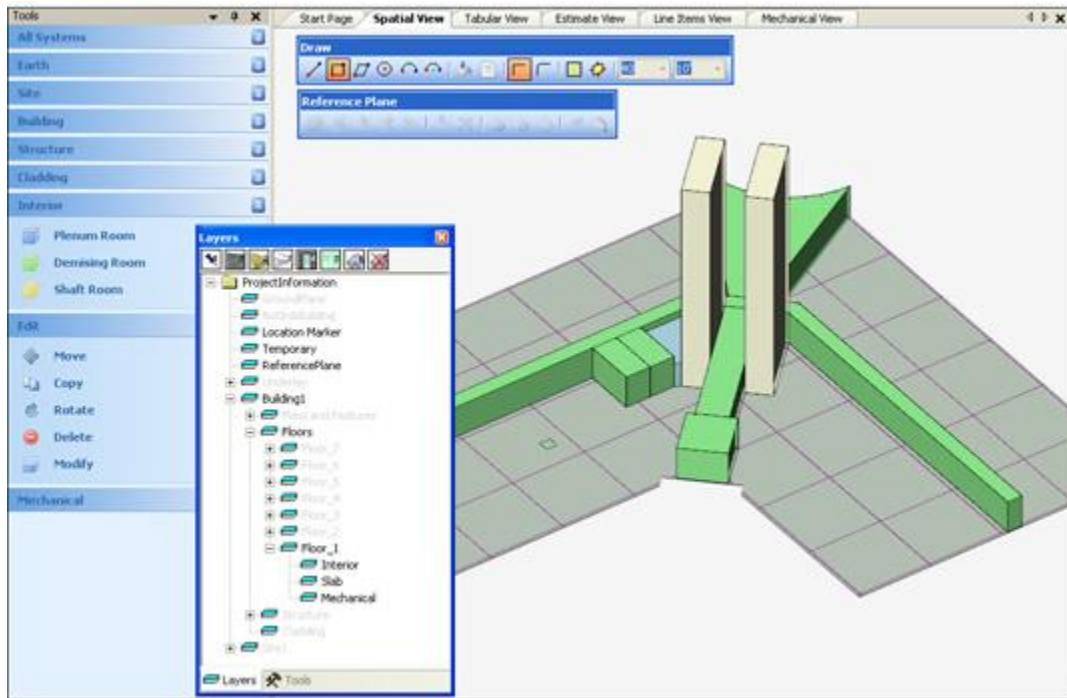


Figure 4 Screen Capture of Model Modification

The screenshot displays a software interface for estimating construction costs. At the top, there are tabs for 'Start Page', 'Spatial View', 'Tabular View', 'Estimate View' (which is active), 'Line Items View', and 'Mechanical View'. Below the tabs are buttons for 'Summarize', 'Expand Grouped Items', and 'Break Out Conceptuals'. A instruction bar says 'Drag a column header here to group by that column'. The main area contains a table of line items with columns for Classification, WBS/UN, Item, Description, Multiplier, Unit, Quantity, Unit Price, Aggregate, and Aggregate Cost. Below this is a summary table with columns for Name, Percentage, Fee Type, Cost, and Cost Per Unit. At the bottom right, it shows 'Total Cost: \$17,028,046.30, Total Cost / SF: \$89.27'.

Classifi...	WBS:UN...	It...	Description	Mul...	Uni...	Qu...	Uni...	Aggregate	Agg. Co...
C1030110	C INTERIO...	0420	Toilet parbtions, cubicles, ceiling hung...	1.000...	\$851.00	153	Unit	\$130,203.00	\$0.68
D5030920	D SERVICES	0110	Internet wiring, 8 data/voice outlets p...	1.000...	\$2,21...	190.7...	M.S.F.	\$422,695.22	\$2.22
D5020145	D SERVICES	2080	Motor installation, three phase, 460V,...	1.000...	\$2,22...	4	Ea.	\$8,907.78	\$0.05
D5030910	D SERVICES	0440	Comm&alarm sys,incls outlets,boxes,c...	1.000...	\$48,5...	3	Ea.	\$145,761.00	\$0.76
D5020140	D SERVICES	0280	Central air conditioning power, 4 watts	1.000...	\$0.50	19074...	S.F.	\$96,249.60	\$0.50
D5020110	D SERVICES	0640	Rcpts incl pl,box, cnd, W,16.5 per 10...	1.000...	\$3.87	19074...	S.F.	\$739,058.10	\$3.87
D5090220	D SERVICES	0300	Uninterruptible power supply w/ stand...	1.000...	\$1,43...	60	kw	\$86,070.59	\$0.45
D5020135	D SERVICES	0320	Miscellaneous power, 1.2 watts	1.000...	\$0.28	19074...	S.F.	\$53,484.72	\$0.28
D5030310	D SERVICES	1010	Telephone wiring for offices & laborat...	1.000...	\$2,61...	190.7...	M.S.F.	\$499,265.73	\$2.62
D5020210	D SERVICES	0240	Floor fixtr recess mtd in dlg, 2 W per S...	1.000...	\$4.35	19074...	S.F.	\$829,432.78	\$4.35
D5090210	D SERVICES	0680	Gen sets,w/btry,chrgr,muf&xftr sw,dsl ...	1.000...	\$359.40	239	kw	\$85,896.60	\$0.45
D5010230	D SERVICES	0520	Feeder installation 600 V, including RG...	1.000...	\$339.06	100	L.F.	\$33,906.00	\$0.18
D5020155	D SERVICES	0440	Mot fdr sys,three ph,feed to 200V 5H...	1.000...	\$9.18	200	L.F.	\$1,835.90	\$0.01
D5010120	D SERVICES	0520	Svce inst,incls bkrs,ring,20' cnd & W,...	1.000...	\$30,8...	2	Ea.	\$61,718.20	\$0.32
D5010240	D SERVICES	0360	Switchgear inst. incl whd, panels & ci...	1.000...	\$34.9...	2	Ea.	\$69,963.00	\$0.37
								\$15,059,1...	\$78.95

Name	Percentage	Fee Type	Cost	Cost Per Unit
General Conditions	5.00 %	Direct	\$752,956.96	\$3.95
Design Allowance	0.00 %	Direct	\$0.00	\$0.00
Inflation Allowance	0.00 %	Direct	\$0.00	\$0.00
General Liability	0.05 %	% of General Conditions ...	\$7,906.05	\$0.04
Excess Liability	0.05 %	% of General Conditions ...	\$7,906.05	\$0.04
			\$1,968,907.15	\$10.32

Total Cost: \$17,028,046.30, Total Cost / SF: \$89.27

Figure 5 Screen Capture of an Estimate

At later stage 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 MS ExcelTM. 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 adjustment 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 \times 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 \times Impact Matrix is shown in Figure 6.

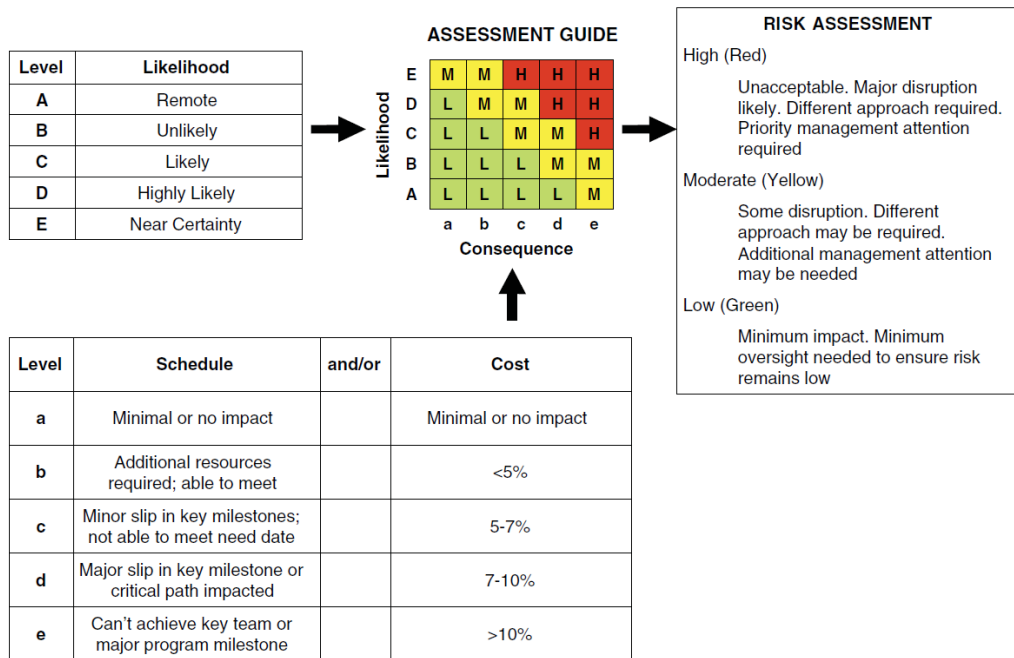


Figure 6 Example of a Probability × Impact Matrix

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 7.



Figure 7 The Three Tier Approach Process to Estimate Project Contingency

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

Type I - risk identification and percentage contingency: for non-complex 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 \times 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.

Type III - quantitative risk analysis and contingency management: for 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 a 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 estimates and the contingency provides the total estimate of project cost. As project definition becomes clear and information of cost elements is available, the baseline estimates increase while the contingency portion should decrease. Regarding contingency estimating method, Olumide et al. (2010) utilized the 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 value. 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 8.

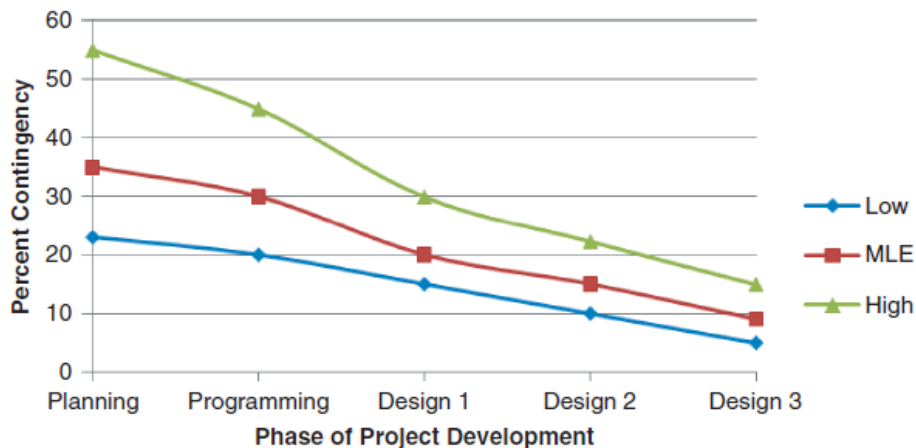


Figure 8 Sliding-scale Contingency for Noncomplex Projects

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 judgment on risk management and qualitative and quantitative analysis results.

Predetermined method - for each AACEI's estimate class stated in Table 1 on Page 15, 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 a 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 of 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 also 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 which 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 cost, 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 utilize more than two methods to estimate cost of risk factors. Expert judgment is a fundamental estimating method and should be combined with any other methods. Analysis results of a parametric model may provide reference on developing a pre-determined estimating method.

CHAPTER SUMMARY

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

CHAPTER III

RESEARCH METHODOLOGY

A clear research methodology ensures that the research objectives of this study are 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 to support conceptual estimating was developed and tested.

METHODOLOGY

The logic of development of this research is shown in Figure 9. The problem identification and literature review discussed in the previous chapters are fundamental to the development of the telephone interview and survey protocols and estimating prototype tool.

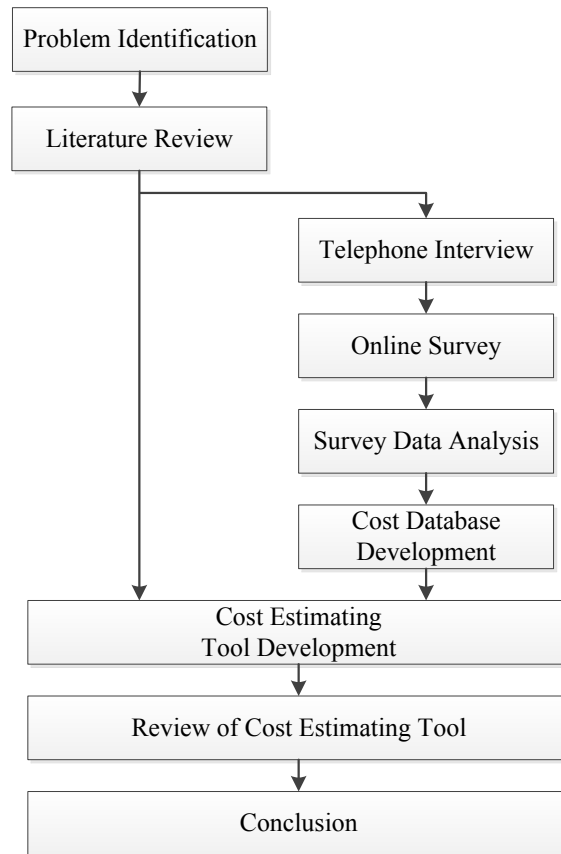


Figure 9 Research Process

Telephone Interview

A telephone interview protocol was developed to better understand the characteristics of rural and small urban transit facilities. Interviewees included personnel at state DOTs, transit managers, and consultants involved in design and construction of rural and small urban 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 were prepared for the discussions.

Telephone Interview Summarization

The summarization of interviews results reflects the typical characteristics of rural and small urban 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 was normalized into the national average in 2014. The results of interviews assisted the design of the survey questions.

Online Survey

Based on the literature review and telephone interview results, survey questions were developed to collect specific historical design and construction costs 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 facility features
- Locations of facilities
- Actual design cost
- Actual construction cost
- Design schedule (start and finish)
- Construction schedule (start and finish)
- Unusual conditions surrounding the projects
- Major facilities component costs of construction

The pilot survey protocols in PDF format were sent to three transit managers, two DOTs 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 Texas A&M Transportation Institute's online survey tool. Potential participants included state DOTs' Section 5311 program managers, transit managers, and consultants. Email addresses were provided by RTAP. With the help of personnel from RTAP, survey invitations explaining background and objectives of the research and 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 to encourage them to participate in the survey. Emails asking 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 into MS ExcelTM where data was normalized into the national average in 2014 before any further data analysis. R.S. 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 period. 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 conditional nearest neighbor method (the value of the nearest city included in the City Cost Index with 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 index 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 (known as JMP, a statistical analysis system), regression analysis was performed at 90% confidence level (10% significance level) in order to find 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

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 square 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 classified into categories. 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 which are combinations of four types of facilities (administration, operation, maintenance, and vehicle storage), seven people provided gross percentages for building sitework. 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 Database Development

The survey data for park and ride, shelter bus stops, un-shelter bus stops, and sign-only bus stops was incomplete or very limited. Therefore, the historical cost data collected to develop the database covers only those facilities in the 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 database, the classification of building elements is the same as the standards of American Society for Testing and Materials (ASTM)' 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 DOTs staff, and consultants). The database includes project location, project type, mid-point of design time, mid-point 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

The development of the cost estimating prototype tool received continuous help and consulting from two experts in the field of cost estimating. The prototype tool was developed in MS ExcelTM based on the survey cost data analysis results. Once the user inputs basic project information, such as project location, size, and the mid-point of design and construction year, this 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 interview and/or online survey. Results of the review helped to improve clarity of the instruction and friendliness of operation setting.

CHAPTER SUMMARY

This chapter discusses the research process and research methods used in this study. Details concerning telephone interview and online survey are presented in Chapter IV and Chapter V. The process of developing cost estimating database and prototype tool is discussed in Chapter VI.

CHAPTER IV

TELEPHONE INTERVIEW

INTERVIEW PROTOCOL

As an additional source to conduct a review of recently designed and constructed rural and small urban transit facilities, a telephone interview process was a useful method for gaining information. A structured interview protocol was developed based on the findings obtained from the literature review. It included 13 questions covering five main areas of rural and small urban transit facilities which are:

- Differences between rural and small urban transit facility projects
- Typical size
- Typical design and construction costs
- Availability of historical cost databases and checklists of critical estimate items
- Typical risk factors and contingency estimation

The duration of each interview was about one hour. Appendix B contains a copy of the project memorandum and interview questions.

INTERVIEW PROCESS

Thirteen potential interviewees, including 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 emails was the first step in the interview process. Six people, including three DOT personnel, two consultants, and one transit manager, expressed their willingness of participating in the interview. The project memorandum and the interview protocol were sent via emails 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, instructions, and confirmed 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 of interest of the interview, understanding the typical characteristics of rural and small urban 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 were summarized in this section. Inputs from DOTs' personnel, transit managers, and consultants were aggregated to reflect typical characteristics of rural and small urban transit facilities.

Differences between Rural and Small Urban Transit Facilities

In small urban areas, transit facilities, such as maintenance buildings and indoor garages, are usually larger due to higher volume of passengers. Further, land is usually difficult to acquire to construct a transit facility. Small facilities, such as passenger shelters, are dominantly located in the urban areas. Although FTA's funding is often 80-20 split where 80 percent goes to urban transit facility projects and 20 percent goes to rural projects, lack of funding for rural transit facilities is one of 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 complexity.

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

Typical Design and Construction Cost

The cost of rural and small urban transit facilities varies based on the following factors: 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 (i.e., Buy America Act compliance).

Generally speaking, the total cost of a rural or small urban transit facility is between 2 to 4 million dollars. The cost can range from 8 to 24 million dollars if a project is located in a west coast area. The cost range of a para-transit facility² is 12 to 16 million dollars. Table 2 shows unit cost of different types of facilities. With more features added, the unit cost would be higher.

Table 2 Unit Cost of Transit Facilities

Facility Type	Unit Cost
Administration	\$150-\$200/square foot
Maintenance	\$300/square foot (the cost depends on what kind maintenance service is performed.)
Open Bus Storage	\$125-\$250/square foot

² Para-transit is an alternative mode of flexible passenger transportation that does not follow fixed routes or schedules.

The Availability of Historical Cost Data

It seems 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 different databases for building construction, mechanical, electrical, plumbing, landscape, and equipment. Both R.S. Means Building Construction Cost Data manual and their own cost databases are used by the cost engineers. Cost analysis is also conducted by cost engineers to identify reasons for cost overruns or underruns.

The Availability of Checklist of Critical Estimate Items

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

- Higher transportation expenses: construction in remote areas increases transportation expenses and need to pay travel time.
- Soil conditions: contaminated soil or unexpected soil conditions.
- Buy America Act compliance: materials made in the United State 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 incrementally 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 bids, 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 change orders. According to the interviewees from state DOTs, 10 to 15 percent of construction cost is often suggested as an appropriate contingency. Design firms usually work with contractors to set 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 transit facilities:

- Project size and costs varies due to different facility types, location, and facility features.
- Project risks were identified, including soil conditions, Buy America Act compliance, and unexpected underground conditions.
- In order to address project risks, contingency is estimated as 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 the estimates provided by consulting firms.

CHAPTER SUMMARY

This chapter discussed the interview protocol development and interview process. Then, results of interview were summarized. The collected qualitative data obtained from telephone interviews was useful input when developing the survey protocol.

CHAPTER V

ONLINE SURVEY

SURVEY PROTOCOL

The main objective of the survey was to collect historical project specific cost data from the State DOTs, transit agencies, and consulting firms. The data was collected on rural and small urban 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
- Other

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

Table 3 Descriptions of Survey Sections

Section	Description
Respondent Information	The name and type the agencies that constructed transit facilities
General Project Information	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Type and size of facilities • Different facilities features and elements
Cost Estimating	<ul style="list-style-type: none"> • The types 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 • Design and construction cost estimating methods • Influential factors in cost estimating process
Schedule	<ul style="list-style-type: none"> • Actual/ estimated design schedule • Actual/estimated construction schedule • Reasons for delays.
Risk	<ul style="list-style-type: none"> • Methods to estimate the construction contingency • Unusual conditions surrounding the projects
Change Orders	<ul style="list-style-type: none"> • The reasons for change orders and their financial impacts on the projects
Other	Lessons about estimating process learned from the project.

Before sending the survey to practitioners in the rural and small urban transit facility industry, the survey protocol was pre-tested in October, 2013. A copy of the pilot survey is provided in Appendix C. Three transit managers and one DOT personnel participated in the pilot survey. The feedback from the pilot survey revealed the respondents had difficulties in locating actual historical cost data and completing the open-ended questions in the fields of cost estimating, scheduling, and risks sections.

Some transit operators lacked cost estimating expertise and they relied on the estimates provided by consulting firms. Therefore, the survey protocol was re-designed 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 the reasons for cost overruns. A copy of the refined survey is provided in Appendix D.

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 the following reasons: a limited number of transit facilities constructed in the 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. A copy of the shortened survey is provided in Appendix E. The descriptions of the main body of the shortened survey are shown in Table 4.

Table 4 Descriptions of the Shortened Survey

Section	Description
Respondent Information	<ul style="list-style-type: none">• The name and type the agencies that constructed transit facilities
General Project Information	<ul style="list-style-type: none">• Project location• Funding source(s)• Project delivery method• Design and construction contract type.
Characteristics of the Project	<ul style="list-style-type: none">• Type and size of facilities• Different facilities features and elements
Cost Estimating	<ul style="list-style-type: none">• The types 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	<ul style="list-style-type: none">• Actual design schedule• Actual construction schedule
Risk	<ul style="list-style-type: none">• Major risk factors• Methods to estimate the construction contingency
Change Orders	<ul style="list-style-type: none">• The reasons for change orders and their financial impacts on the projects
Other	<ul style="list-style-type: none">• The availability of the cost estimating database and willing to share

SURVEY PROCESS

The survey process is shown in Figure 10.

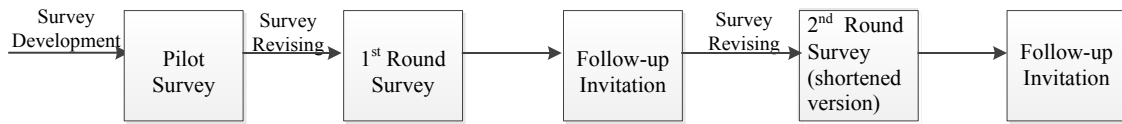


Figure 10 Survey Process

While the second round survey was distributed, telephone calls to 25 transit managers across the United State were made to encourage them to participate in the online survey. In order to collect more cost data, invitations of the shortened survey were distributed among 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 at the end of February, 2014. 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 time). Only one transit manager replied and provided a design and construction schedule for the project.

SURVEY DATA ANALYSIS

Table 5 shows 26 projects' original design and construction costs data collected through the online survey. Different types of facilities are combined in most of the

projects. 11 out of the 26 projects consist of two or three types of facilities (e.g. administration and operations, or administration, operations, and vehicle storage). Among the 11 projects, one project was a renovation project. Nine projects include four types of facilities (administration, operations, maintenance, and vehicle storage). Two projects are concerning small passenger facilities (shelter bus stop and/or sign only bus stop). Three projects include not only administration, operations, maintenance, vehicle storage, but also passenger facilities (e.g. park and ride, shelter bus stop, un-shelter bus stop, and sign-only bus stop). Thus, the data was incomplete concerning park and ride, shelter bus stop, un-shelter bus stop, and sign-only bus stop. The cost data that can be used to conduct the analysis only covers those new facilities construction in the administration, operations, maintenance, and vehicle storage.

However, years of design and/or construction of eight projects were not provided by respondents. Constructions of two projects were not completed till the respondents' submitting the surveys. Then, design and/or construction costs of these ten projects could not be converted to the year of 2014. 11 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 limited amount of design and construction cost data.

Table 5 Survey Design and Construction Cost Data

#	Mid-point of Design	Mid-point of Construction	Facility Type	Project Size (sf)	Estimated Design Cost (\$)	Actual Design Cost (\$)	Estimated Construction Cost (\$)	Actual Construction Cost(\$)
1	08/2008	03/2009	Operation	6,000	130,000	130,000	1,170,000	1,170,000
2			Administration, Operation	19,000	216,246	291,020	1,889,067	734,440
3	07/2011	04/2013	Operation,Maintenance	8,300	120,000	130,000	1,200,000	1,300,000
4	08/2012	06/2013	Operation, Vehicle Storage	6,720	-	-	277,637	277,637
5	10/2011	12/2012	Operation, Vehicle Storage	28,000	446,980	550,658	3,980,000	4,594,000
6	10/2011	07/2012	Administration, Operation	4,078		129,677	1,345,760	1,371,694
7		10/2012	Operation, 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, Operation, Vehicle Storage	36,967	350,000	353,000	3,739,432	3,756,481
11			Administration, Operation, Vehicle Storage	17,000	250,000	252,632	2,500,000	2,323,192
12	11/2006	08/2008	Operation,Maintenance,Vehicle Storage	8,184	43,600	41,950	545,000	524,312
13	11/2009	02/2010	Administration, Operation, Maintenance, Vehicle Storage	29,030	482,000	482,000	4,088,000	4,800,000
14	05/2006		Administration, Operation, Maintenance, Vehicle Storage	16,500	200,000		4,790,000	
15	04/2000	03/2005	Administration, Operation, Maintenance, Vehicle Storage	30,000	129,500	154,370	2,450,000	2,329,000

Table 5 Continued

#	Mid-point of Design	Mid-point of Construction	Facility Type	Project Size (sf)	Estimated Design Cost (\$)	Actual Design Cost (\$)	Estimated Construction Cost (\$)	Actual Construction Cost(\$)
16	01/2010	Not Completed	Administration, Operation, Maintenance, Vehicle Storage	70,000	1,500,000	2,000,000	30,000,000	
17	01/2012	05/2012	Administration, Operation, Maintenance, Vehicle Storage	2,000		16,600	122,500	133,100
18	09/2012		Administration, Operation, Maintenance, Vehicle Storage	33,295	450,000		6,816,772	
19	01/2010	06/2011	Administration, Operation, Maintenance, Vehicle Storage	40,000	1,586,500	1,586,500	7,557,392	7,872,283
20	05/2011	10/2011	Administration, Operation, Maintenance, Vehicle Storage	12,500				
21	10/2009	Not Completed	Administration, Operation, Maintenance, Vehicle Storage	75,000	2,000,000	2,000,000	30,000,000	
22	10/2009	07/2010	Shelter bus stop	100	6,000	7,500	90,000	128,000
23	09/2011		Shelter bus stop, Sign-only bus stop	30	-	-	6,691	7,531
24	08/2007	03/2010	Administration, Operation, Maintenance, Vehicle Storage, Park and ride	32,000				
25	08/2013		Administration, Operation, Maintenance, Vehicle Storage, Small Passenger Facility, Shelter bus stop, Un-shelter bus stop, Sign-only bus stop	75,000	95,000		950,000	
26	10/2006	06/2008	Administration, Operation, Maintenance, Vehicle Storage, Small passenger facility, Shelter bus stop	45,000	70,696	81,686	1,390,762	1,364,494

Before further data analysis, all design and construction cost data was normalized by performing the following two steps. First, all actual design and construction cost data was adjusted from various locations to national average costs by using the City Cost Index in R.S. Means Building Construction Cost Data manual. For locations not included in the City Cost Index, the conditional nearest neighbor (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 to conduct an analysis. Facility types cover administration, operations, maintenance, and vehicle storage.

Table 6 Construction Cost Data

#	Mid-point of Construction	Facility Type	Project Size (sf)	Estimated Construction Cost (\$)	Actual Construction Cost(\$)	Normalized Construction Cost (\$)
1	03/2009	Operation	6,000	1,170,000	1,170,000	1,220,406
2	04/2013	Operation,Maintenance	8,300	1,200,000	1,300,000	1,635,071
3	06/2013	Operation, Vehicle Storage	6,720	277,637	277,637	311,131
4	12/2012	Operation, Vehicle Storage	28,000	3,980,000	4,594,000	4,201,247
5	07/2012	Administration, Operation	4,078	1,345,760	1,371,694	1,444,681
6	10/2012	Operation, 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	Operation,Maintenance,Vehicle	8,184	545,000	524,312	593,875
9	02/2010	Administration, Operation, Maintenance, Vehicle Storage	29,030	4,088,000	4,800,000	5,517,413
10	03/2005	Administration, Operation, Maintenance, Vehicle Storage	30,000	2,450,000	2,329,000	3,698,384
11	05/2012	Administration, Operation, Maintenance, Vehicle Storage	2,000	122,500	133,100	129,813
12	06/2011	Administration, Operation, Maintenance, Vehicle Storage	40,000	7,557,392	7,872,283	8,586,186

The number of projects in construction cost analysis is 12. The range of normalized construction cost is from \$129,813 to \$8,586,186 and the mean value is \$2,437,699. The plot of the normalized construction cost and project size is shown in Figure 11. Regression analysis was performed to identify the relationship between the normalized construction cost and project size for rural and small urban transit facilities.

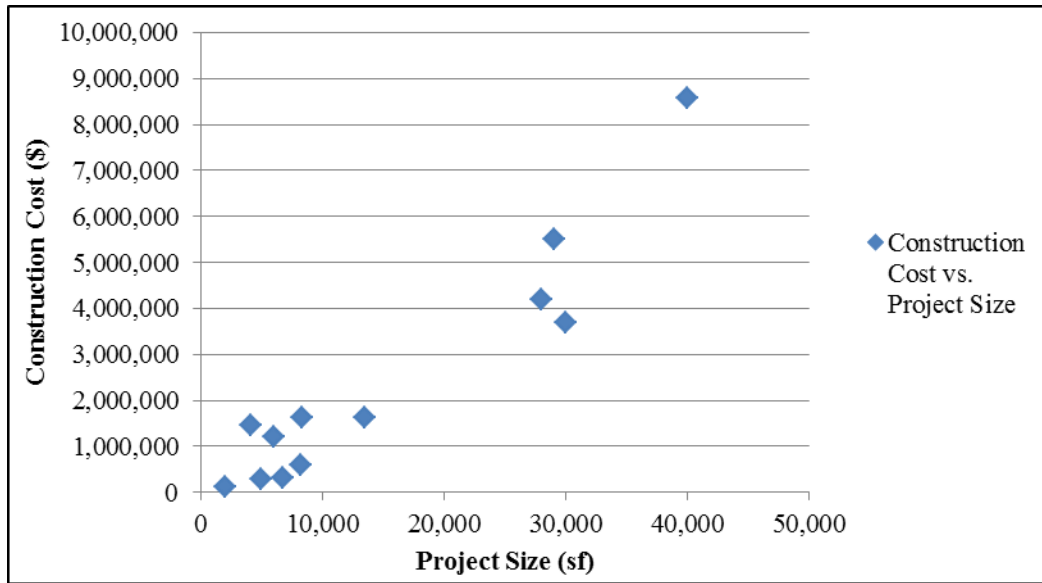


Figure 11 Plot of the Normalized Construction Cost and Project Size

The normalized data was fitted with a straight line regression model at 90% confidence level. The regression plot and statistical summary are shown in Figure 12.

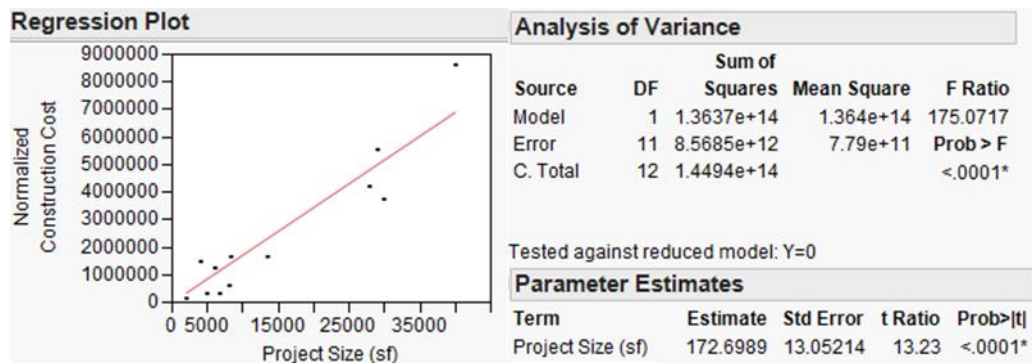


Figure 12 Construction Cost Analysis - Regress Plot and Statistical Report of Straight Line Regression

Let construction cost and project size be Y and X respectively. At 90% confidence level, the straight line regression model is $Y = 172.6989 X$ ($X > 0$).

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

According to the statistic report above, the p-value is $<0.0001 < \alpha=0.1$. Null hypothesis should be rejected. That is, a straight line regression model is needed. The R square =

$$\frac{SS_{mdeol}}{SS_{total}} = \frac{1.3637e+14}{1.4494e+14} = 0.940872085, \text{ which indicates that the straight line regression}$$

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 the ASTM Unifomat II. There are seven major group elements: 1) building sitework, 2) substructure, 3) shell, 4) interiors, 5) services, 6) equipment and furnishings, and 7) 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 transit projects. Assuming that various combinations of facility types give rise to a different percentage of construction cost for each construction system, projects were categorized into the following two groups: projects including four types of facilities (administration, operation, maintenance, and vehicle storage), and projects including two or three of those facility types (e.g. administration and operation).

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 in Figure 13. If the project includes two or three types of those facilities mentioned above, the percentage breakdown for each construction system is shown in Figure 14.

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

- Larger percentage of building sitework construction cost of 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 are more types of facilities involved in a project.
- Larger percentages of interior and equipment and furnishings construction costs of the first combination might be due to the necessity of more wall, floor, and ceiling finishes, interior doors, partitions, and furnishings constructions if more facility types are included in a project.
- Larger percentages of shell and services construction costs of the second combination might be due to the fact that projects including operation, maintenance, and/or vehicle storage might require more heating, ventilation, and air conditioning (HVAC), plumbing, and electrical constructions to ensure services or activities can be performed safely and efficiently.

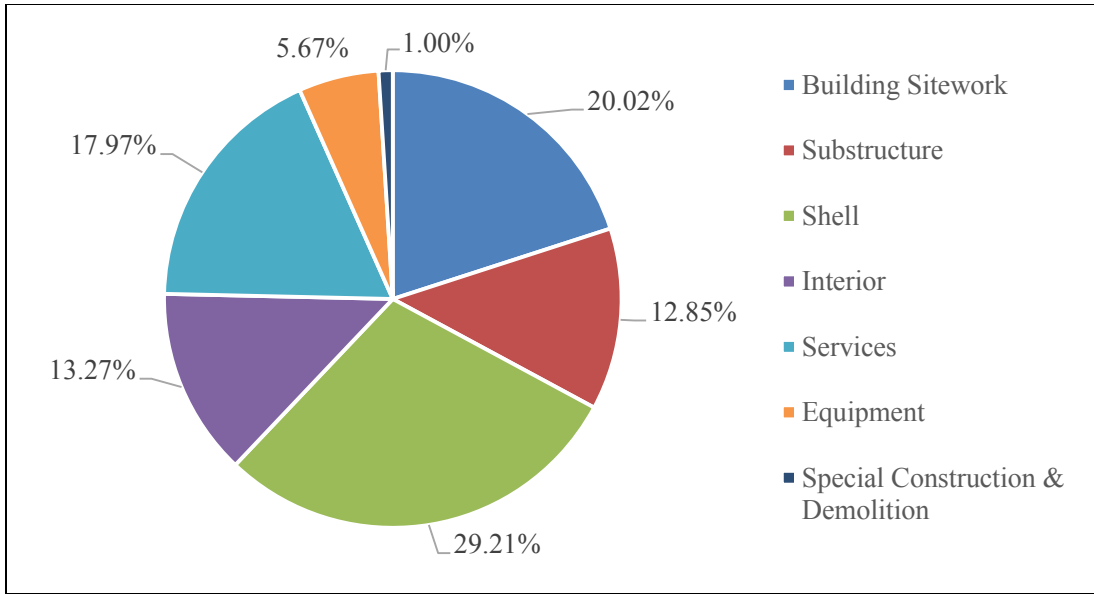


Figure 13 Percentage of Construction Cost for Each Construction System (Combination I)

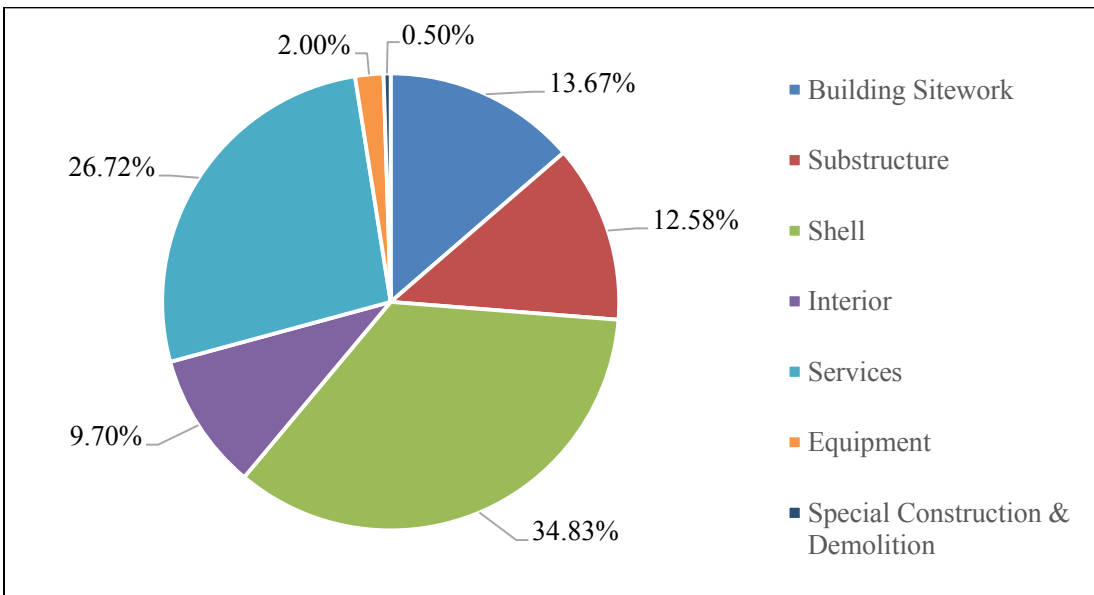


Figure 14 Percentage of Construction Cost for Each Construction System (Combination II)

Design Cost Estimating

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

Table 7 Summary of Design Cost Estimating Methods

Design Cost Estimating Method	Number of Projects
Similar Projects	11
Hours to Design	5
Similar Project & Hours to design	2
Similar Project & Historical Percentage of Construction Cost	1
Contractor's estimates	1
Architects' estimates	1
Historical Percentage of Construction Cost	1
Bid	1

Table 8 shows estimated, actual, and normalized design cost data available to perform a data analysis. For projects that lacked actual design cost, their estimated design costs were assumed to be the same as the actual design costs. The number of projects in design cost analysis is 14. The normalized design cost ranges from \$ 16,190 to \$2,632,715 and the mean value is \$ 706,533. The plot of the normalized design cost and project size is shown in Figure 15.

Table 8 Design Cost Data

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

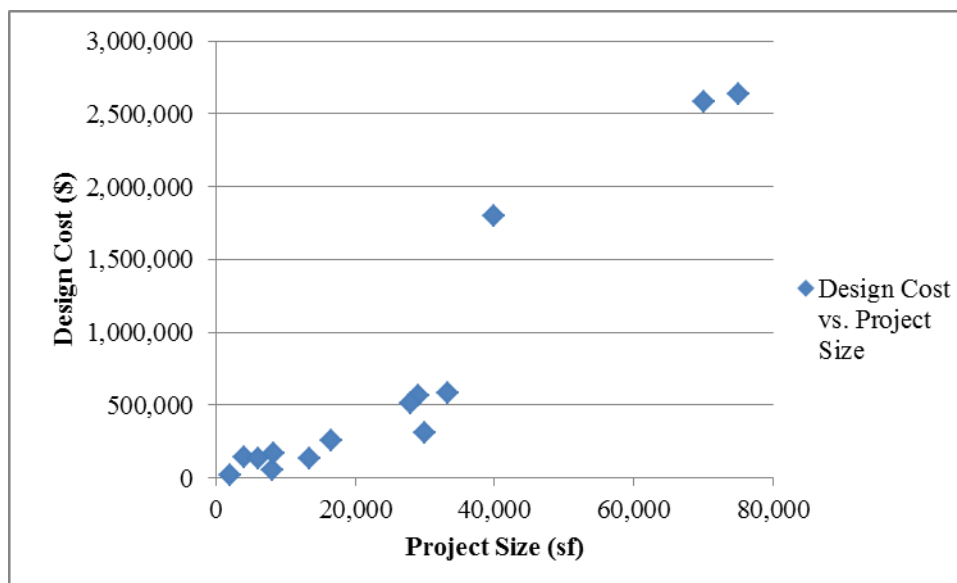


Figure 15 Plot of the Normalized Design Cost and Project Size

The normalized design cost data was fitted with a straight line regression model with 90% confidence level. The regression plot and statistical summary are shown in Figure 16.

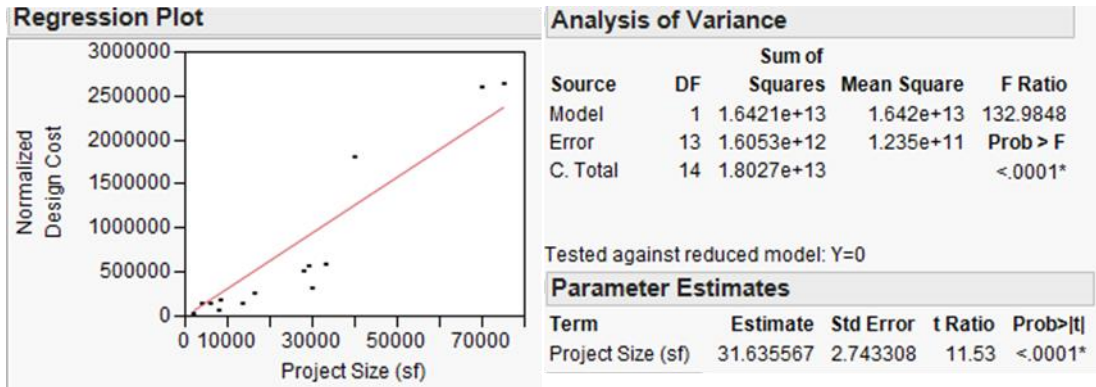


Figure 16 Design Cost Analysis - Regress Plot and Statistical Report of Straight Line Regression

Let design cost and project size be Z and X respectively. At 90% confidence level, the straight line regression model is $Z = 31.635567 X$ ($X > 0$). In order to prove the necessity of this model, a hypothesis test was conducted at 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.

According to the statistic report above, the p-value is $0.0001 < \alpha = 0.1$. Null hypothesis should be rejected. That is, a straight line regression model is needed. The R square =

$$\frac{SS_{model}}{SS_{total}} = \frac{1.6421e+13}{1.8027e+13} = 0.910911411, \text{ which indicates that the straight line regression}$$

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 17. Soil conditions and unexpected underground conditions are two the most frequent risk factors and most interviewees also suggested these two risks. Contaminated soil, buried debris, and unexpected utilities can increase project cost and also cause unanticipated delay during construction. Compared with the interview results concerning risks, the survey respondents also considered risks 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 the archeological 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 might be that there was sufficient contingency in the estimated construction cost or project control plans were carried out effectively by the project management teams.

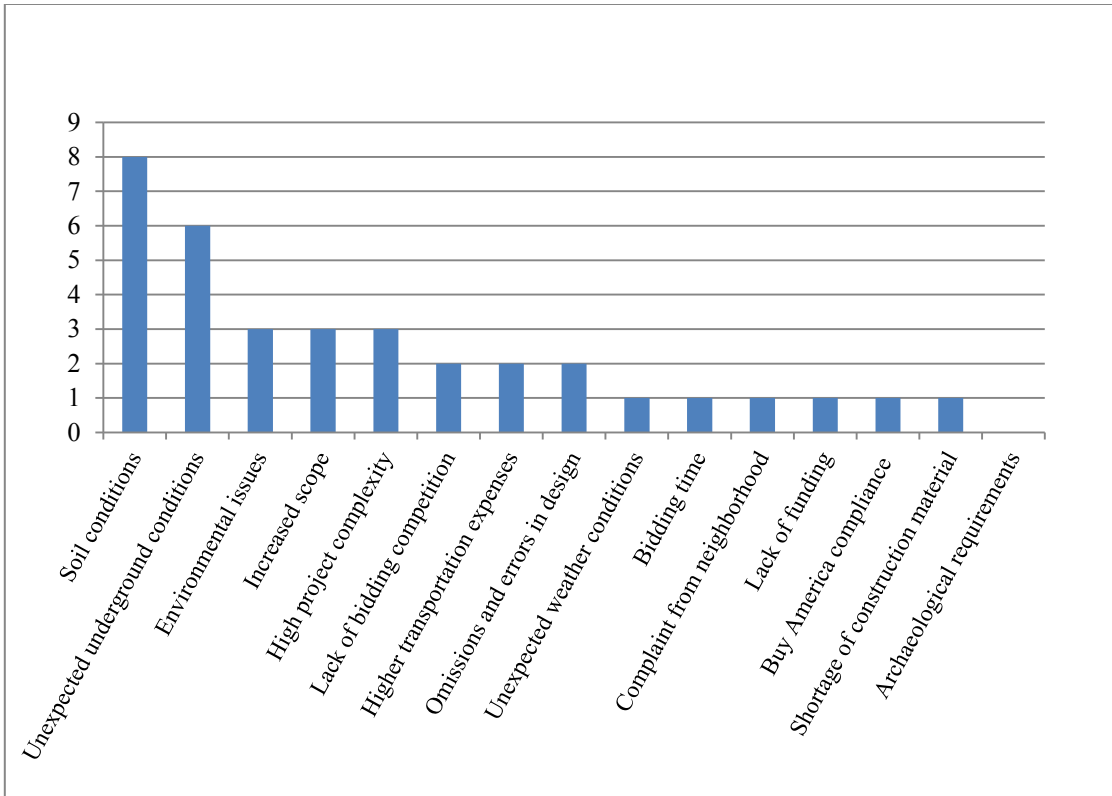


Figure 17 Frequency of the Risk Factors

Contingency Estimating

Although 21 out of 26 respondents stated that a percentage of construction cost was used to estimate 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 median of contingency is 10%.

CHAPTER SUMMARY

This chapter first summarized 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 transit facility projects were discussed at the end of this chapter. The analysis results supported the development of cost estimating database and prototype tool.

CHAPTER VI

DEVELOPMENT OF COST ESTIMATING DATABASE AND PROTOTYPE

TOOL FOR RURAL AND SMALL URBAN TRANSIT FACILITIES

COST ESTIMATING DATABASE DEVELOPMENT

After gathering and classifying actual historical cost data through surveys, all data were input into a MS ExcelTM spreadsheet and were adjusted to national average cost in 2014 by using the 2014 version R.S. 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, operation, maintenance, and vehicle storage, but the types exclude passenger facility (small and large), park and ride, bus stop (shelter and unshelter), and sign only bus stop. Most projects in the database are combinations of administration, operation, maintenance, and vehicle storage. The cost estimating database was constructed excluding land acquisition and had the following features:

- Basic Project Information: city, state, the mid-point of design time (Month/Year), the mid-point 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 sitework (%), substructure (%), shell (%), interiors (%), services (%), equipment & furnishings (%), and special construction & demolition (%).

Screen captures of the database are shown in Figure 18, Figure 19, and Figure 20.

The screenshot shows an Excel spreadsheet titled 'NCHRP20-65-Task3 - Excel'. The spreadsheet is divided into two main sections: 'Basic Project Information' and 'Project Duration'. The 'Basic Project Information' section includes columns for '# - City', 'State', 'Mid-point of Design', 'Mid-point of Construction', 'Location', and 'Facility Type'. The 'Project Duration' section includes columns for 'Design Duration (month)' and 'Construction Duration (month)'. The data is organized into rows, with the first row (row 1) serving as a header for the 'Basic Project Information' section, and the second row (row 2) serving as a header for the 'Project Duration' section. The data rows start from row 3 and continue down to row 22.

Basic Project Information						Project Duration		
# - City	State	Mid-point of Design	Mid-point of Construction	Location	Facility Type	Design Duration (month)	Construction Duration (month)	
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 18 Cost Database - Basic Project Information and Project Duration

#	City	State	Project Size (sf)	Estimated Design Cost (\$)	Actual Design Cost (\$)	Estimated Construction Cost (\$)	Actual Construction Cost (\$)
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 19 Cost Database - Project Cost Information

#	City	State	Building Sitework (%)	Substructure (%)	Shell (%)	Interiors (%)	Services (%)	Equipment & Furnishings (%)	Special Construction & Demolition (%)
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 20 Cost Database - Percent of Construction Cost for Each Construction System

COST ESTIMATING PROTOTYPE TOOL DEVELOPMENT

The types of rural and small urban transit facilities include administration, operation, maintenance, vehicle storage, park and ride, shelter bus stop, un-shelter bus stop, and sign-only bus stop. The historical cost data collected to develop the database in support of this prototype tool covers 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 facilities, 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 cost of the combination of the first four facility types.

The tool is considered a prototype due to limited historical cost data collected and used to develop the cost database. The database was developed in MS ExcelTM 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 captures.

Introduction

The cost estimating prototype tool is a MS ExcelTM file. Once the user opens the tool, the "Introduction" tab will be shown. In order to ensure the tool works properly, the user is required to read the introduction with care before starting the cost estimating process. The screen captures of the introduction section are shown in Figure 21.

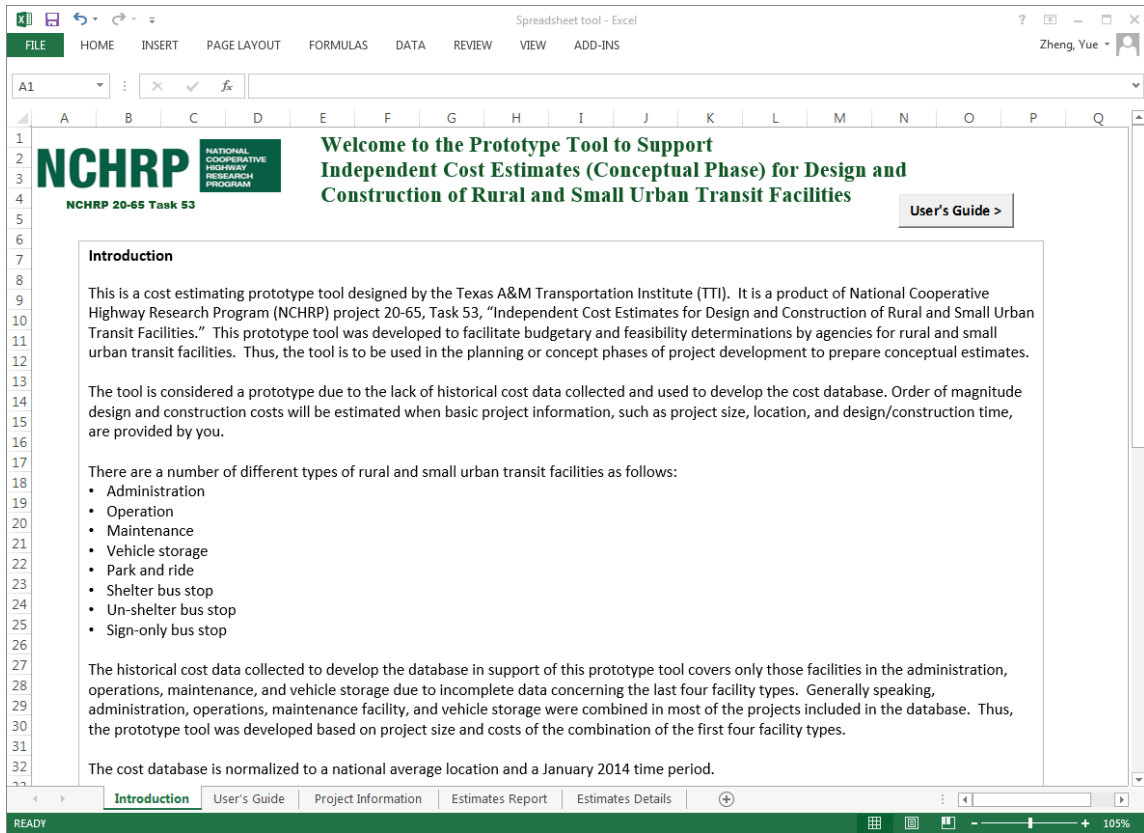


Figure 21 Screen Capture of the Cost Estimating Prototype Tool – Introduction

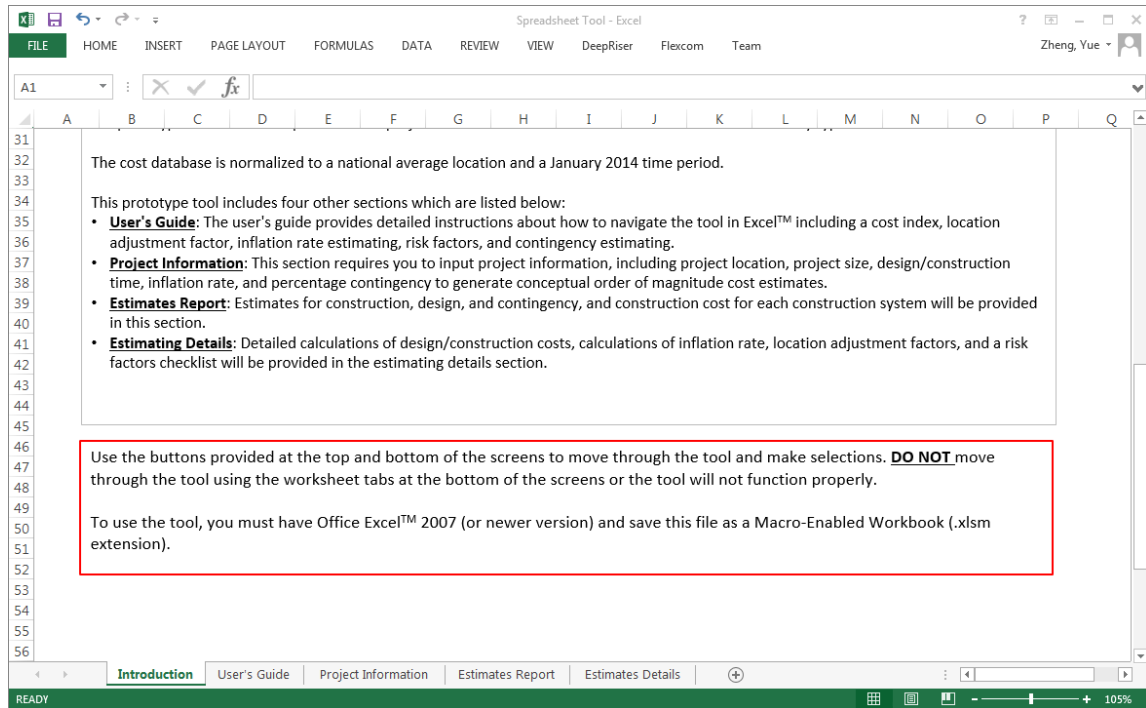


Figure 21 Continued

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, and tips of navigation and document saving.

User's Guide

The “User’s Guide” tab explains tips for using the tool. The tips include five aspects: how to navigate the tool, how to save and print the estimate results, 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 2025. The tool suggests the user should carefully evaluate any estimates made using this tool after the five year mark

(after 2020). The user can either choose the default inflation rate (2.5 percent) or input a value based on their knowledge of local economic condition. The default inflation rate was set after consulting two experts in cost estimating.

In this prototype tool, contingency is estimated as percentage of construction cost. The user can either choose the default percentage range or input a contingency percent based on their knowledge about 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 from 10 percent to 25 percent and most likely contingency percentage is 15 percent. The default contingency percentages were set by the experts in cost estimating based on the results of interview and online survey and their estimating experience. Before setting contingency, the tool recommends the user should assess the risk factors listed in the tool to ensure that sufficient amount of contingency is estimated.

As for the location adjustment factor, the estimating prototype tool has ten regions within the United States according to Office of Management and Budget (OMB) Circular A-105 (Wikipedia 2014). For each region, 20 cities, including metropolis and small cities, were selected, and cost indices of those cities from 2014 version R.S. Means Building Construction Cost Data manual were utilized to calculate the location factor. The chosen cities, population, and cities' indexes are attached in Appendix F. The location adjustment factor for each region is listed in Table 9. The index of national average is 100. The prototype tool uses the equation below to adjust design and construction costs from the national average to any particular region.

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

Table 9 Regions and Location Adjustment Factors

Region's Name	Location 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

The screen captures of this section are shown in Figure 22. After reading the tips, the user can go to the “Project Information” tab by clicking the “Continue” button.

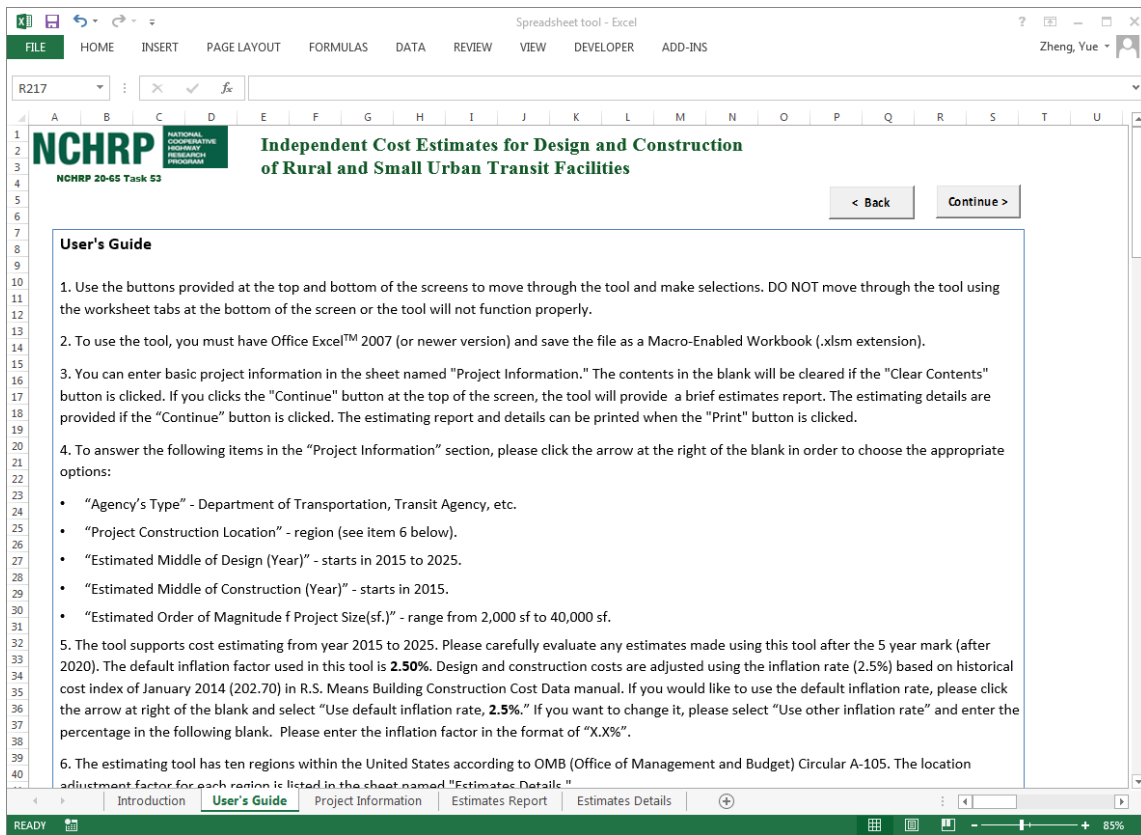


Figure 22 Screen Capture of the Cost Estimating Prototype Tool – User's Guide

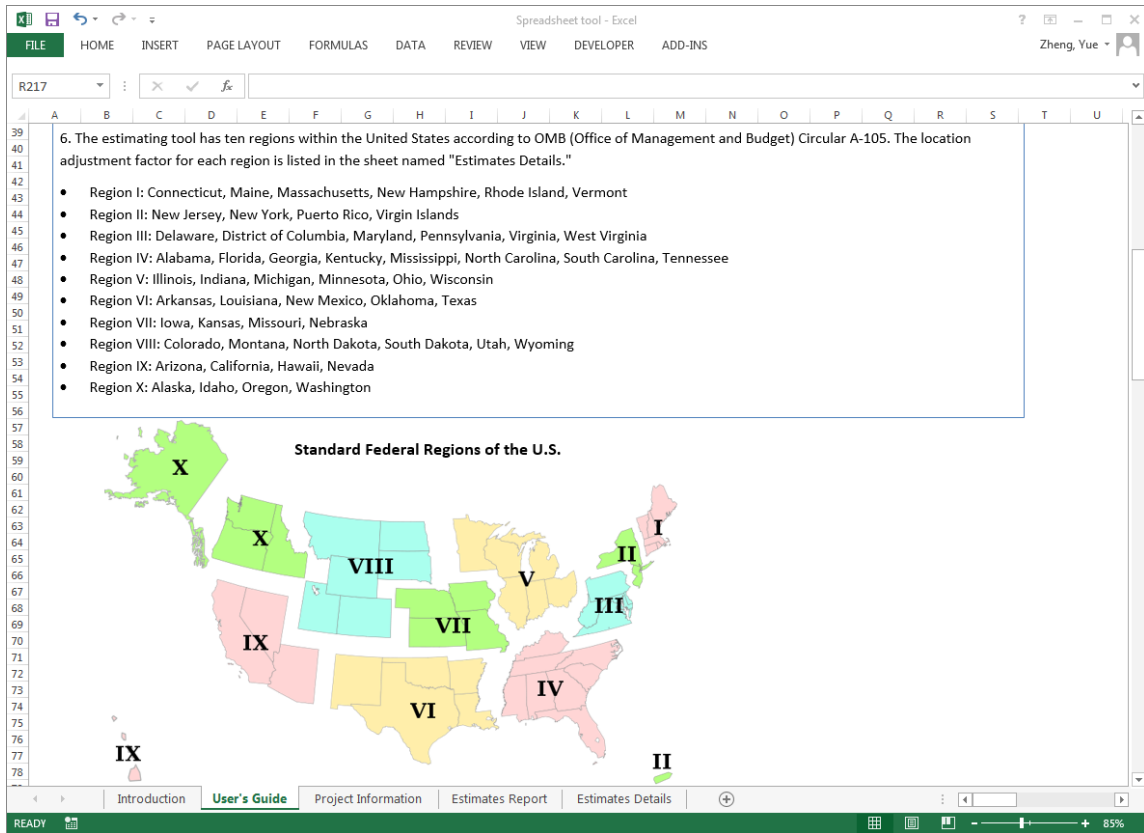


Figure 22 Continued

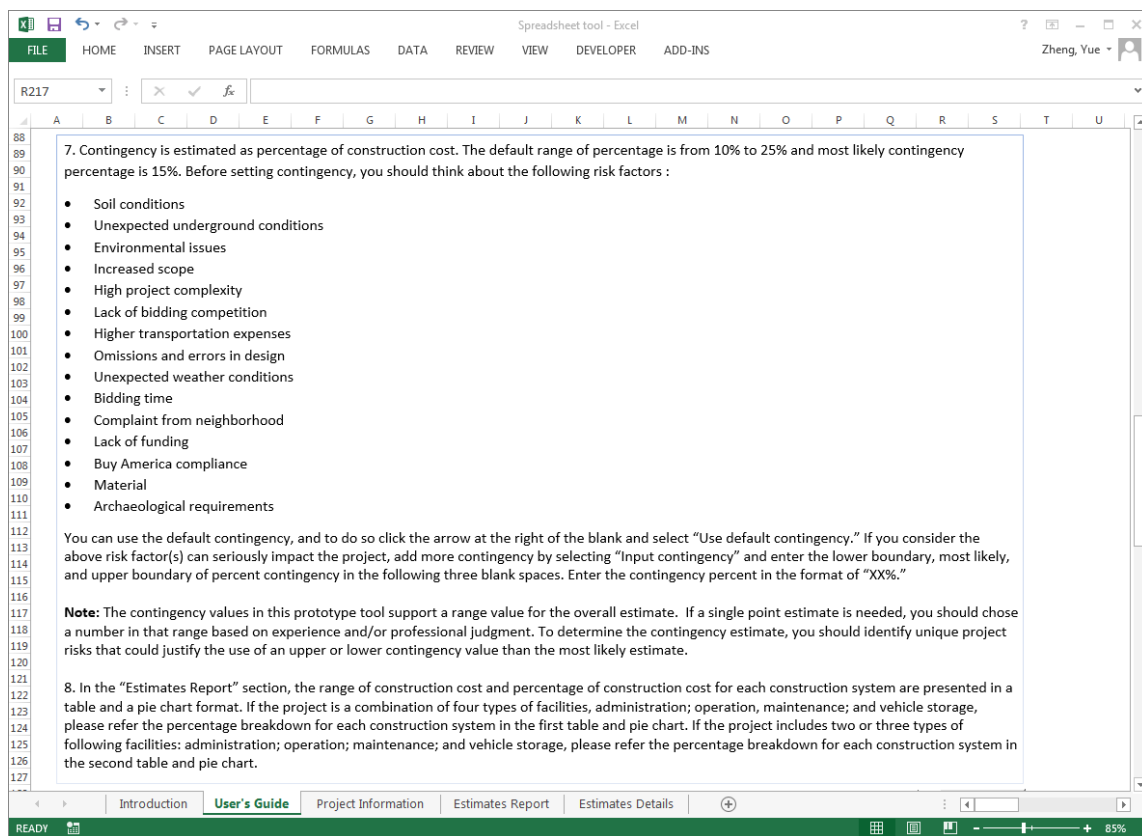


Figure 22 Continued

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 mid-point 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 23. For the user's reference, the tool provides the user default values for the inflation rate and contingency percent (lower boundary, most likely, and upper boundary). However, users can also input the values of those variables based on their knowledge about the project. To facilitate the user to

estimate a proper range of contingency percent, a recommendation is provided. 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.

The screenshot shows a Microsoft Excel spreadsheet titled "Independent Cost Estimates for Design and Construction of Rural and Small Urban Transit Facilities". The spreadsheet is set to the "Project Information" tab. The form contains the following fields and instructions:

- Agency Name:** Text input field.
- Agency Type:** Dropdown menu. Instruction: "Please choose one of the following options by clicking the".
- Project Name:** Text input field.
- Project Owner(s):** Text input field.
- Project Construction Location:** Dropdown menu. Instruction: "Please choose one of the following options by clicking the".
- Estimated Middle of Design (Year):** Dropdown menu. Instruction: "Please choose one of the following options by clicking the".
- Estimated Middle of Construction (Year):** Dropdown menu. Instruction: "Please choose one of the following options by clicking the".
- Estimated Order of Magnitude of Project Size (sf):** Text input field. Instruction: "Please enter project size ranging from 100 sf to 40,000 sf."
- Use default inflation rate, 2.5%?** Dropdown menu. Instruction: "Please enter 'X.X%' in this blank. DOT NOT forget to input percentage mark."
- Use default contingency?** Dropdown menu.
- The lower boundary of contingency (%):** Text input field. Instruction: "Please enter 'XX%' in this blank. DOT NOT forget to input percentage mark."

Navigation buttons: "< Back", "Clear Content", and "Calculate and Continue >".

Figure 23 Screen Capture of the Cost Estimating Prototype Tool – Project Information

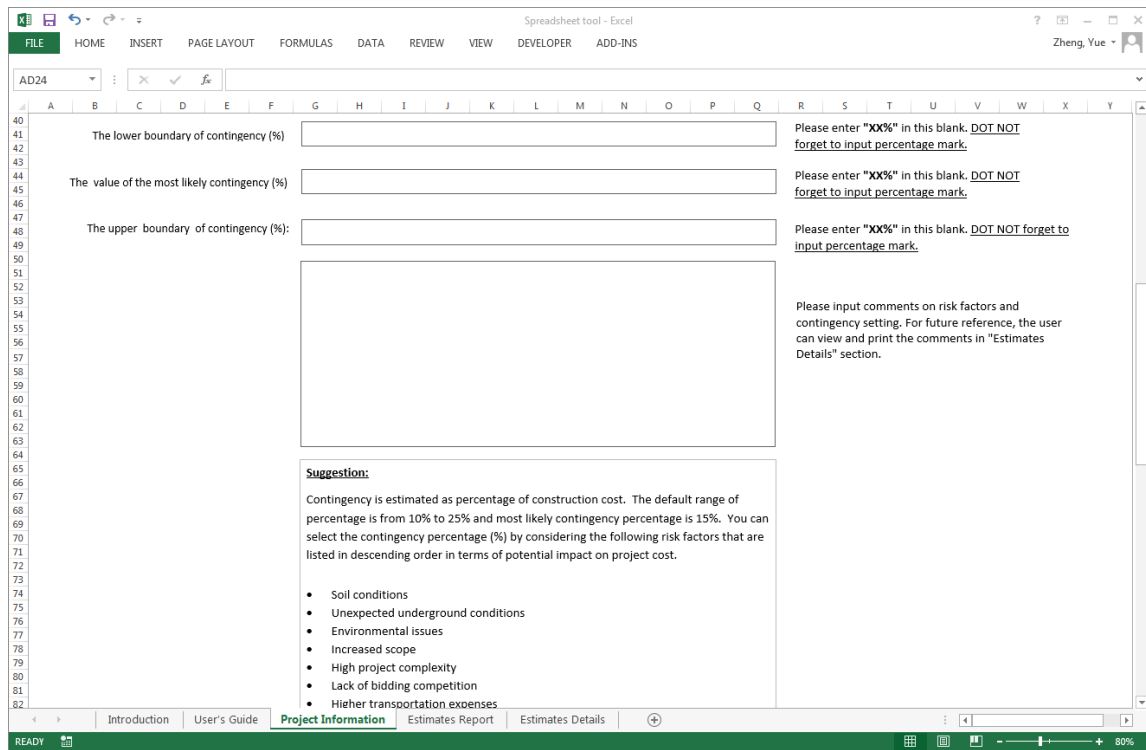


Figure 23 Continued

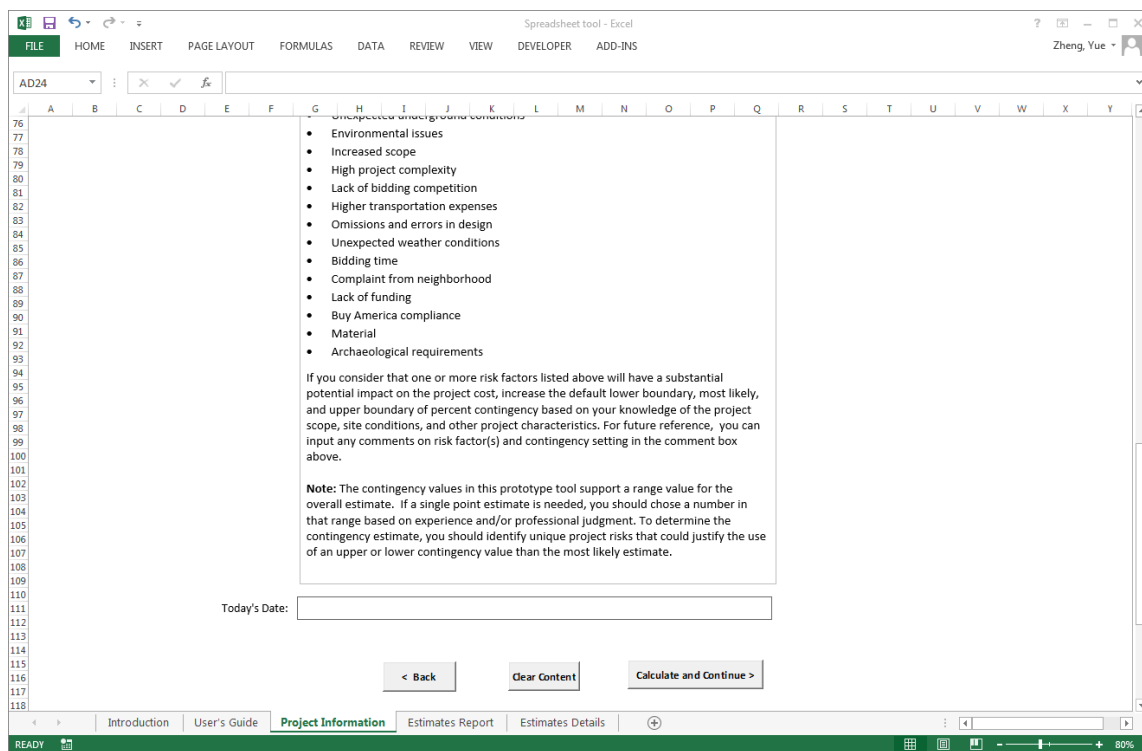


Figure 23 Continued

Estimates Report

The “Estimate Report” tab generates the estimates based on the user’s input. Estimates 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 cost, exclusive of project contingency, are estimated by using the regression functions described in Chapter V. The sum of base construction cost and contingency comprises a total construction cost.

The screen captures of this tab are shown in Figure 24. The user can print the report by clicking the “Print” button at the top of the screen. To review estimates details, the user should click “Continue” to go to the “Estimates Details” tab.

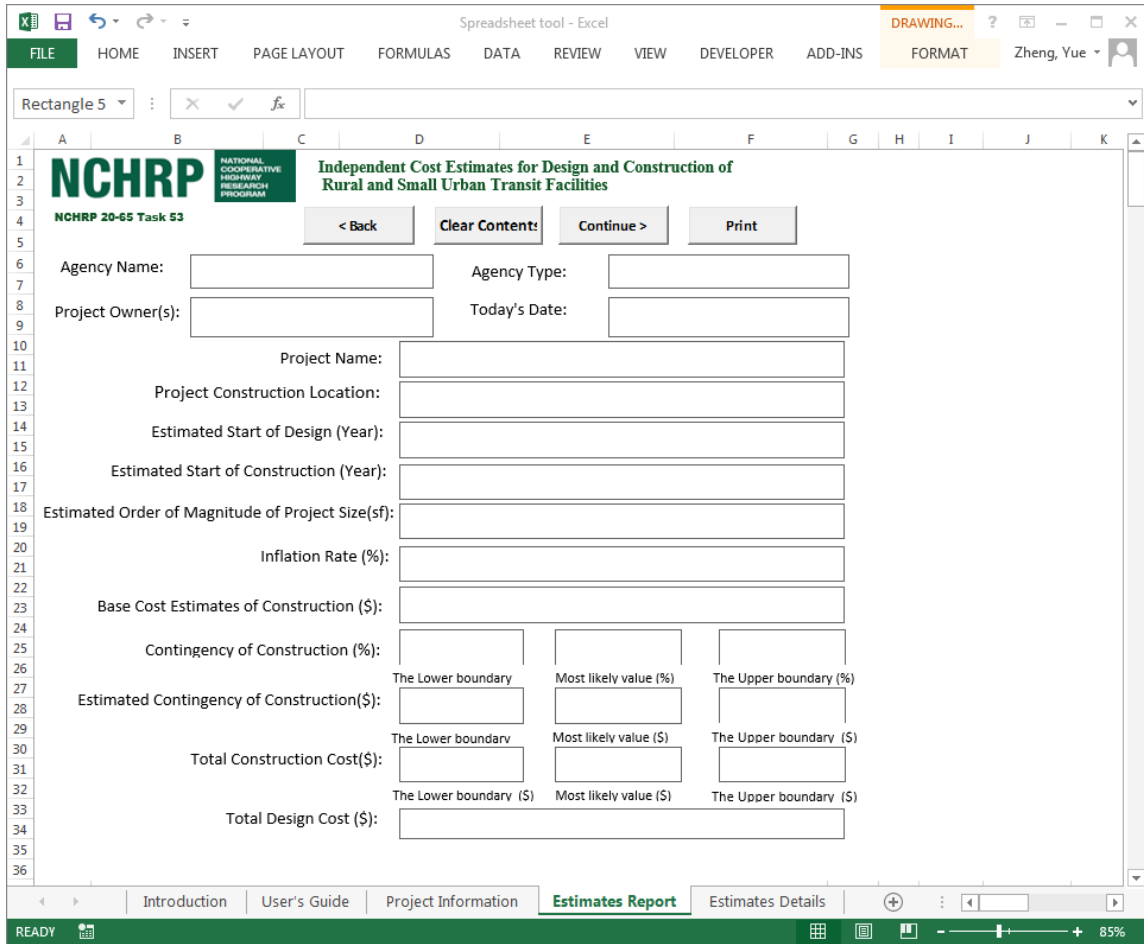


Figure 24 Screen Capture of the Cost Estimating Prototype Tool – Estimates Report

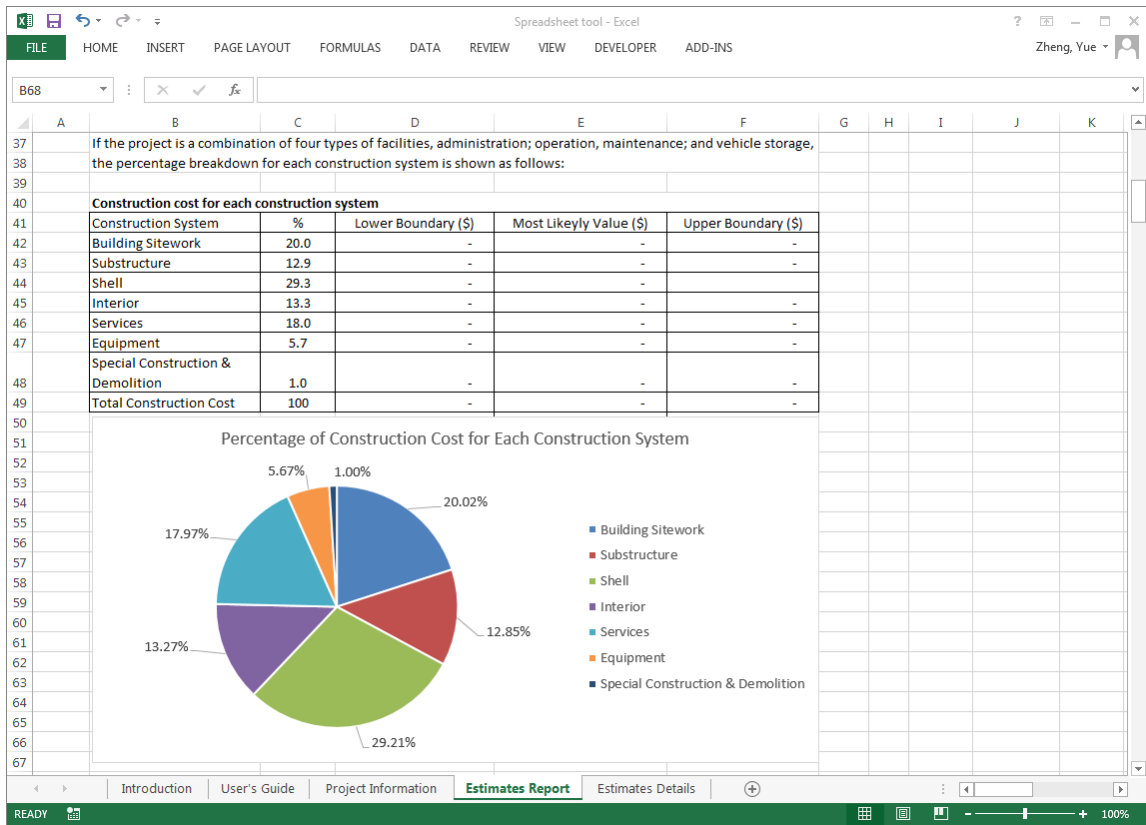


Figure 24 Continued

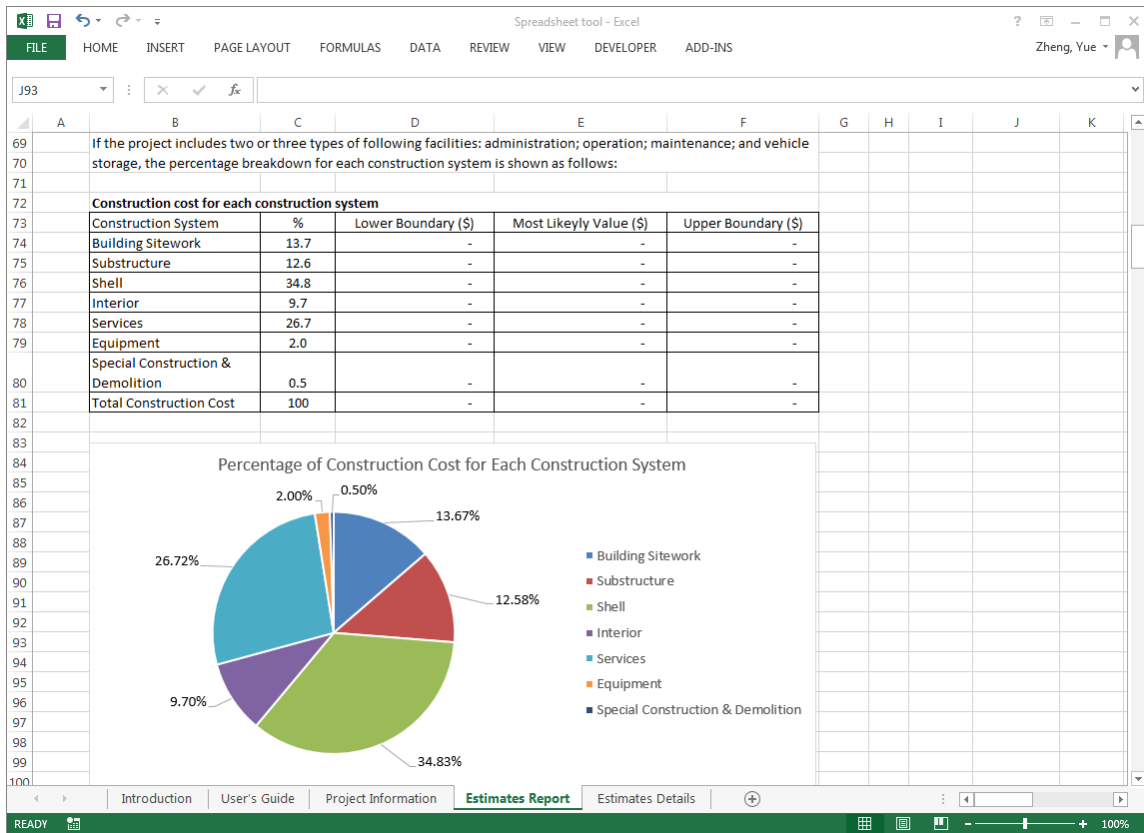


Figure 24 Continued

Estimates Details

The “Estimates Details” tab provides the user the detailed calculations of an estimate and the historical index information. The user can also review the location factor for each region, risk factors, and any comments the user inputs in the “Project Information” tab. The screen captures of this tab are shown in Figure 25. For future reference, the user can print information in this tab by clicking the “Print” button.

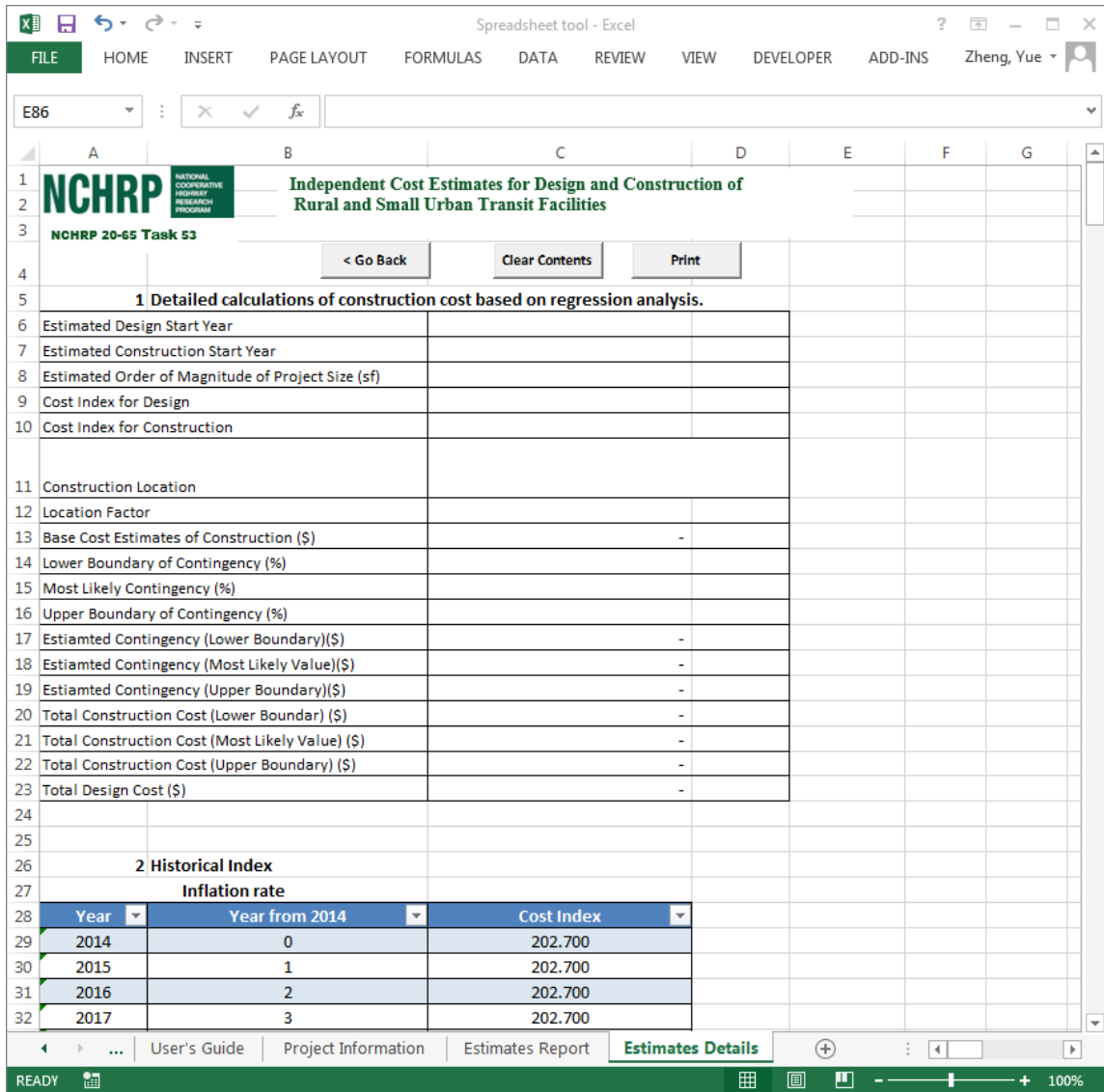


Figure 25 Screen Capture of the Cost Estimating Prototype Tool – Estimates Details

Spreadsheet tool - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW DEVELOPER ADD-INS Zheng, Yue

E86

	A	B	C	D	E	F	G
23	Total Design Cost (\$)		-				
24							
25							
26	2 Historical Index						
27	Inflation rate						
28	Year	Year from 2014	Cost Index				
29	2014	0	202.700				
30	2015	1	202.700				
31	2016	2	202.700				
32	2017	3	202.700				
33	2018	4	202.700				
34	2019	5	202.700				
35	2020	6	202.700				
36	2021	7	202.700				
37	2022	8	202.700				
38	2023	9	202.700				
39	2024	10	202.700				
40	2025	11	202.700				
41							
42							
43	3 Location Factor						
44							
45		Region's Name	Location Factor				
46		Region I: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	103.085				
47		Region II: New Jersey, New York, Puerto Rico, Virgin Islands	107.565				
48		Region III: Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia	96.010				

User's Guide | Project Information | Estimates Report | **Estimates Details**

READY 100%

Figure 25 Continued

Spreadsheet tool - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW DEVELOPER ADD-INS Zheng, Yue

E86

	A	B	C	D	E	F	G
48		Region III: Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia	96.010				
49		Region IV: Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee	84.325				
50		Region V: Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin	99.495				
51		Region VI: Arkansas, Louisiana, New Mexico, Oklahoma, Texas	83.295				
52		Region VII: Iowa, Kansas, Missouri, Nebraska	91.580				
53		Region VIII: Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming	86.730				
54		Region IX: Arizona, California, Hawaii, Nevada	102.005				
55		Region X: Alaska, Idaho, Oregon, Washington	102.125				
56							
57							
58		4 Ranking of Risk Factors					
59		Ranking	Risk Factors				
60		1	Soil conditions				
61		2	Unexpected underground conditions				
62		3	Environmental issues				
63		4	Increased scope				
64		5	High project complexity				

User's Guide | Project Information | Estimates Report | **Estimates Details**

READY 100%

Figure 25 Continued

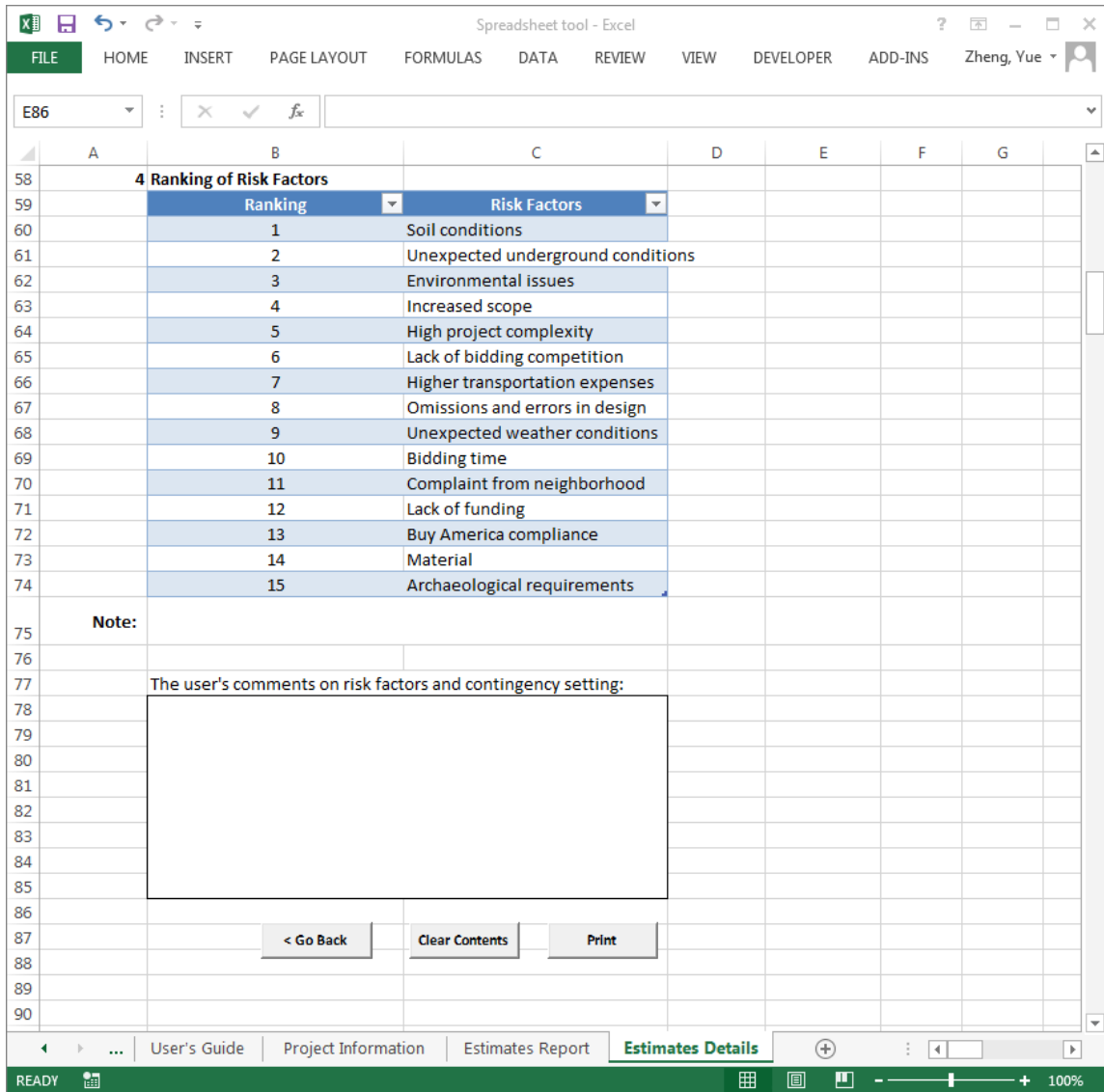


Figure 25 Continued

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 accuracy of its estimates due to the limited database. Throughout the cost estimating prototype tool development, two cost estimating experts provided persistent help and reviewed and tested the prototype tool. They recommended the contingency be estimated as a range with high, most likely, and low value rather than a specific value during conceptual estimating phase. Therefore, 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 on the economic conditions and prediction of labor and material costs of the building construction industry. The projects were classified into two categories after consulting the experts. The reasons for the classification are that administration, operation, maintenance, and vehicle storage are combined in most of the projects collected through the online survey and different combinations have different percentage 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 DOTs 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.

Moreover, an ExcelTM file including a list of rural transit facility projects constructed in Texas was provided by Texas Transportation Institute (TTI). Project size, year of construction, location, and cost were included in the file. However, this file does not explicitly explain what the cost represents (e.g. total construction cost, design costs, or estimated total construction costs). Assuming the cost listed in the file is total construction cost, 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 have similar order of magnitude with the costs provided in TTI's file, other estimates had great differences. The difference 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 when TTI documented the project cost data.

STEPS OF COST ESTIMATING PRACTICE AND COST ESTIMATING MANAGEMENT

The steps of cost estimation practice and cost estimation management were developed based on the guidance in NCHRP Project 8-49, “Procedures for Cost Estimation and Management for Highway Projects during Planning, Programming, and Preconstruction” and the “Minnesota Department of Transportation Cost Estimation Improvement and Organizational Improvement for Project, Phases III and IV”. 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 transit facility estimates. The five-step estimating process initiated by Anderson et al. (2007) is provided as follows:

- Determine Estimate Basis (e.g. project scope, location, and unique characteristics)
- Prepare Base Estimate (techniques and tools, historical database, and adjustment factors)
- Determine Risk and Set Contingency (uncertainty in estimate basis and base estimate to determine the dollar amount of contingency)
- Review and Approve Estimate (structured approach to verify completeness, estimate data used, documentation, and accountability for estimate)
- Communicate Estimate (convey basis, assumptions, and uncertainty)

Appendix H shows the descriptions for each cost estimation step. The cost estimating prototype tool in the research can facilitate all the estimating steps mentioned

above. 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 should be prepared by following the five-step estimating process above.

First, when determining the estimate basis of this project, the transit manager should define 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 manger should input the following key information into the estimating prototype tool: project size (e.g. 6000 square foot); 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 would potentially increase construction cost).

Second, in order to prepare base estimate, the transit manger should select an appropriate estimating approach and a tool supporting conceptual cost estimating. Assumptions, such as 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 mid-point of design year (e.g. 2015), the estimated mid-point of construction year (e.g. 2016), and 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 26.

The screenshot shows an Excel spreadsheet with the following form fields and values:

- Agency Name:** ABC
- Agency Type:** Transit Agency
- Project Name:** Administration and maintenance construction
- Project Owner(s):** New transit complex administration and maintenance
- Project Construction Location:** Region III: Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia
- Estimated Middle of Design (Year):** 2015
- Estimated Middle of Construction (Year):** 2016
- Estimated Order of Magnitude of Project Size (sf):** 6,000
- Use default inflation rate, 2.5%?:** Use other inflation rate (3.0%)
- Use default contingency?:** Input contingency
- The lower boundary of contingency (%):** 10%

Buttons at the top include: < Back, Clear Content, Calculate and Continue >

Navigation tabs at the bottom: Introduction, User's Guide, Project Information (active), Estimates Report, Estimates Details

Figure 26 Screen Capture of ABC Project –Project Information

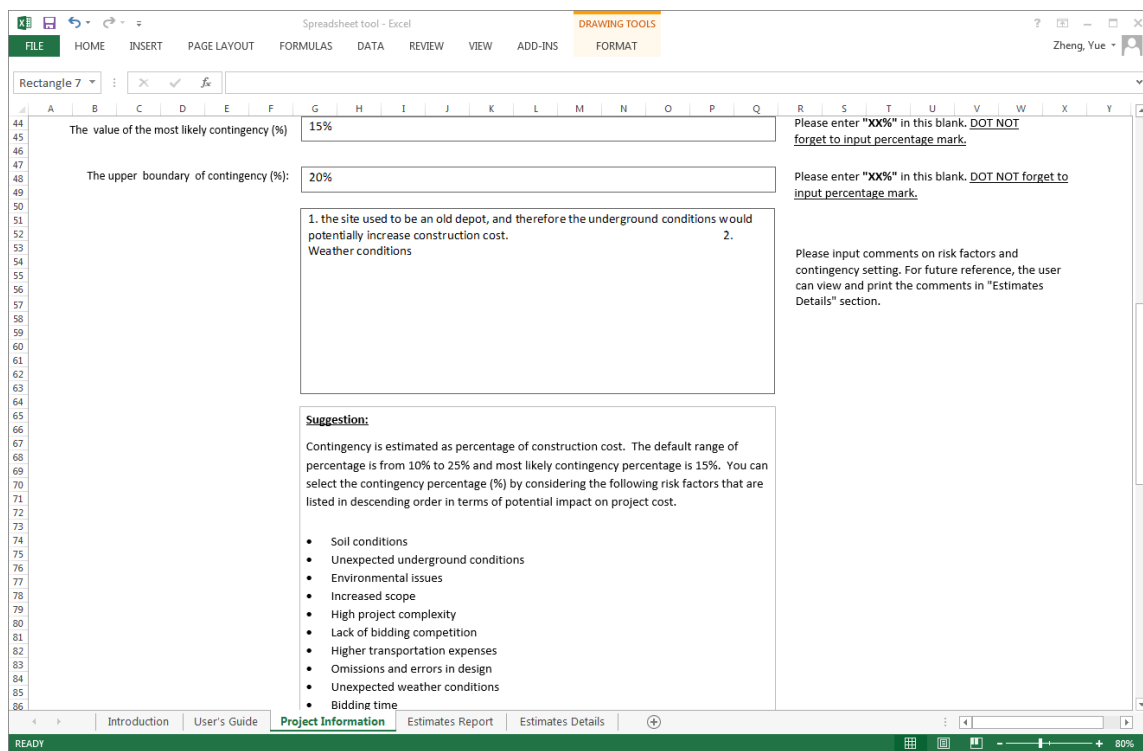


Figure 26 Continued

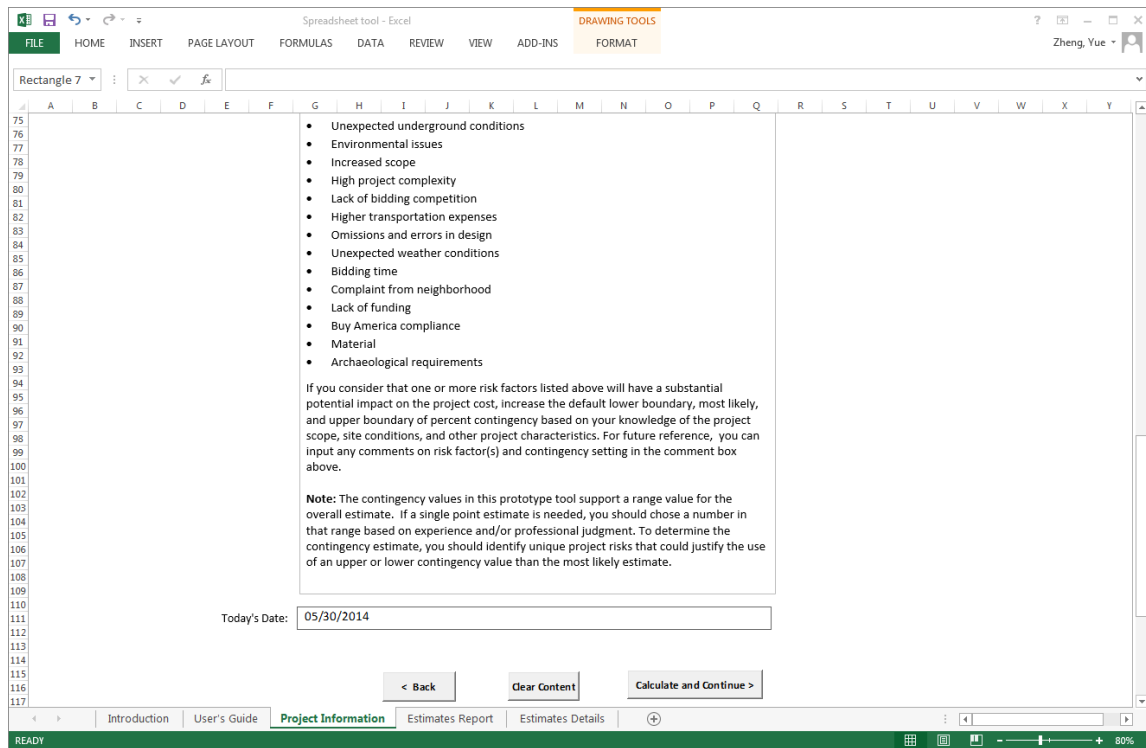


Figure 26 Continued

Fourthly, 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 27 and Figure 28.

Last, in order to communicate the estimates, the transit mangers can print the estimate report and estimate details that convey estimate basis, assumptions, and project risks.

Spreadsheet tool- ABC.xlsm - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW DEVELOPER

H49

NCHRP NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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

NCHRP 20-65 Task 53

< Back Clear Contents Continue > Print

Agency Name: ABC Agency Type: Transit Agency

Project Owner(s): New transit complex Today's Date: 05/30/2014

Project Name: Administration and maintenance construction

Project Construction Location: Region III: Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia

Estimated Start of Design (Year): 2015

Estimated Start of Construction (Year): 2016

Estimated Order of Magnitude of Project Size(sf): 6,000

Inflation Rate (%): 3.0%

Base Cost Estimates of Construction (\$): 1,055,400

Contingency of Construction (%): 10% 15% 20%

Estimated Contingency of Construction(\$):

	The Lower boundary (%)	Most likely value (%)	The Upper boundary (%)
Estimated Contingency of Construction(\$):	105,500	158,300	211,100

Total Construction Cost(\$):

	The Lower boundary (\$)	Most likely value (\$)	The Upper boundary (\$)
Total Construction Cost(\$):	1,161,000	1,214,000	1,267,000

Total Design Cost (\$): 188,000

Project Information **Estimates Report** Estimates Details

READY 100%

Figure 27 Screen Capture of ABC Project –Estimates Report

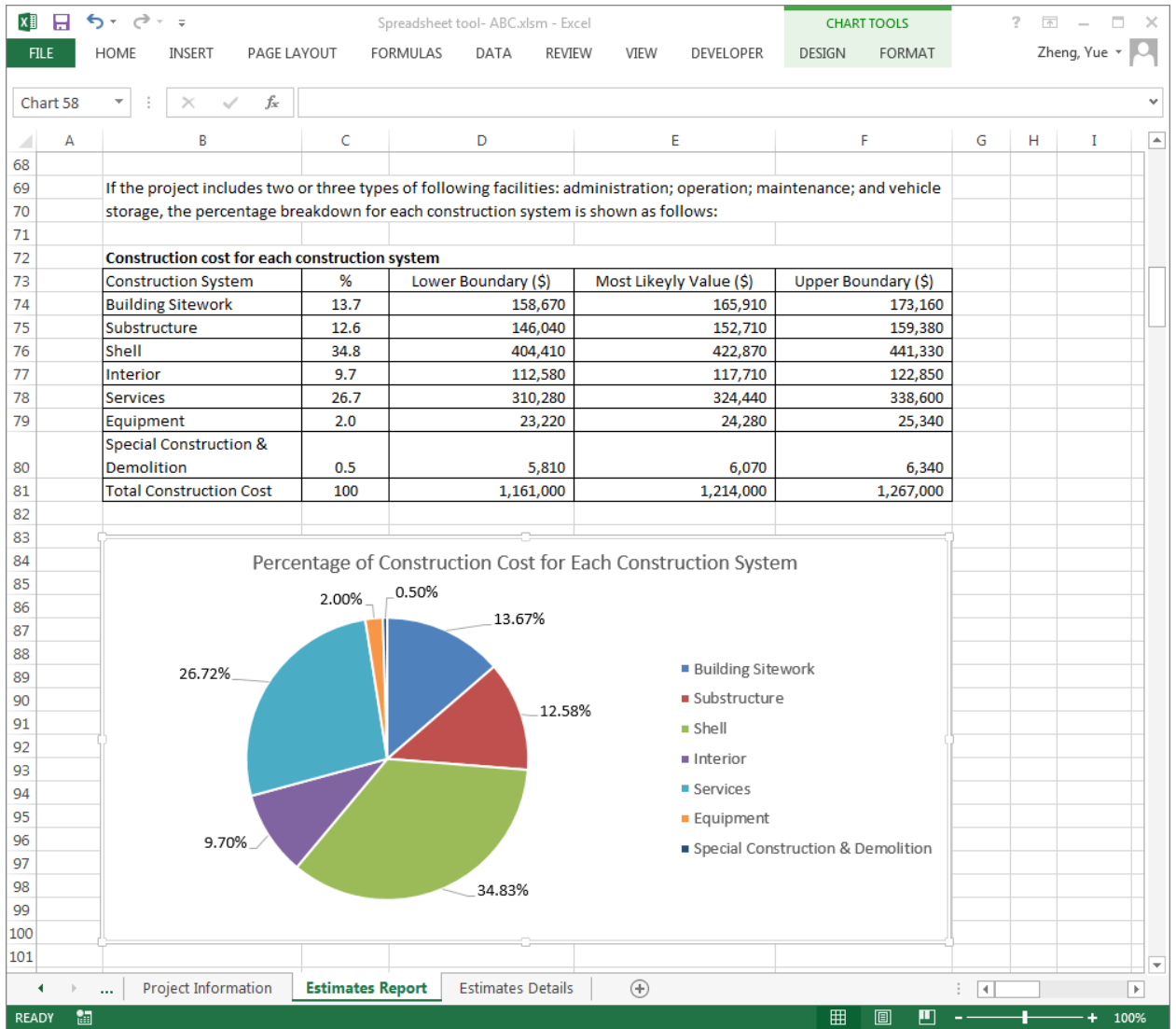


Figure 27 Continued

Spreadsheet tool- ABC - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Team Zheng, Yue

D39

NCHRP NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
NCHRP 20-65 Task 53

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

<Go Back Clear Contents Print

1 Detailed calculations of construction cost based on regression analysis.

6	Estimated Design Start Year	2015
7	Estimated Construction Start Year	2016
8	Estimated Order of Magnitude of Project Size (sf)	6,000
9	Cost Index for Design	208.781
10	Cost Index for Construction	215.044
11	Construction Location	Region III: Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia
12	Location Factor	96.010
13	Base Cost Estimates of Construction (\$)	1,055,400
14	Lower Boundary of Contingency (%)	10%
15	Most Likely Contingency (%)	15%
16	Upper Boundary of Contingency (%)	20%
17	Estiamted Contingency (Lower Boundary)(\$)	105,500
18	Estiamted Contingency (Most Likely Value)(\$)	158,300
19	Estiamted Contingency (Upper Boundary)(\$)	211,100
20	Total Construction Cost (Lower Boundar) (\$)	1,161,000
21	Total Construction Cost (Most Likely Value) (\$)	1,214,000
22	Total Construction Cost (Upper Boundary) (\$)	1,267,000
23	Total Design Cost (\$)	188,000

Project Information Estimates Report **Estimates Details**

READY 110%

Figure 28 Screen Capture of ABC Project –Estimates Details

LIMITATION OF THE RESEARCH

The cost estimating database and prototype tool only support conceptual estimating during 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 transit facilities. The following factors might give rise to lack of data:

- A limited number of transit facilities were constructed in rural and small urban areas in the last five years.
- Majority of the potential survey participants in the contacts database provided by RTAP are state DOTs personnel and transit managers. Many seem to lack the cost estimating knowledge to complete survey or the data simply not kept.
- Respondents have difficulty in accessing projects' design and construction cost data.
- Division of public transit program of state DOTs and transit agencies have experience staff shortages, and therefore DOTs 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 larger scale of data collection with extended amount of time. Design consultants and contractors would be another source for historical cost data.

CHAPTER VII

CONCLUSIONS

This chapter provides summary of conclusions that were drawn from this study, and it recommendations for future research with respect to this topic.

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 cost estimating prototype tool. The general conclusions include:

- Project design and construction costs depends on various factors, such as facility types, project size, location, and facility features.
- Many construction projects for rural and small urban 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 the estimates prepared by consultants. State DOTs hire consultants to perform independent cost estimates 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 were obtained from the online survey.
- In order to address project risks, contingency is estimated as percentage of construction cost. The ranges of contingency percentage given by the interviewees. Survey results provided reference on 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 survey. 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 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 transit projects were the combinations of many types of facilities, such as administration, operation, 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 was incomplete concerning park and ride, shelter bus stops, un-shelter bus stops, and sign-only bus stops. Efforts in collecting data on the cost of those types of facilities should be made in the future.

Lastly, cost and schedule impacts of each risk factor should be asked in the survey so risk factors can be quantified, and therefore risk analysis and management for rural and small urban transit facilities could be better structured.

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APPENDIX A

PROCESS FOR FACILITY CONSTRUCTION (RURAL TRANSIT PROGRAM, ODOT)

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 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 tentative estimates based on similar projects, consultation with city/county engineering staff, etc.

- B. Complete a Feasibility Study to document your need for the facility, to conduct site selection, as well as preliminary drawings and environmental work. To the extent feasible, prepare preliminary design sketches and provide pictures and/or schematics of existing facilities with estimated costs;

Step 2:

A. Apply for Funding

1. Submit application;
2. Complete scoping process;
3. Following scoping process, application approval, and contract approval, for construction projects, proceeds with Phase 1 work outlined below.

- 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 occur, additional environmental work will need to be conducted, or alternative site selected, repeated;
 - (6) Site Development (construction only);
 - (7) Prepare construction bid documents; and
 - (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; and
 - 2. Development bid/proposal for project oversight services and obtain ODOT concurrence
 - a. Select project manager
 - b. Negotiate contract.

Step 3:

- 1. Apply for funding for Phase 2, Construction.
 - 1. Submit application; and

2. Following approval and contract execution with ODOT, proceed with next steps.
2. Bid construction project
 1. Negotiate contract; and
 2. Monitor construction (construction manager).
3. 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 orders;
 5. Report progress and any problems to grantee; and
 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 on-going 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, etc. and ODOT must still review and approve selection process and contracts.
- As noted above, 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.

APPENDIX B

INTERVIEW PROTOCOL

NCHRP 20-65-Task 53: Independent Cost Estimates for Design and Construction of Rural and Small Urban Transit Facilities

As part of National Cooperative Highway Research Program (NCHRP) project 20-65, Task 53, this research focuses on “Independent Cost Estimates for Design and Construction of Rural and Small Urban Transit Facilities.” It is being conducted by the Texas A&M Transportation Institute (TTI). The purpose of this study is to provide guidance to state transit agencies in assisting their sub-recipients with the preparation accurate design and construction cost estimates and processes for reviewing the estimates. A standard estimating methodology (i.e., critical process steps) and a database of key estimate items (i.e., estimating checklists) will be developed specifically for rural and small urban transit facilities to assist agencies in preparing cost estimates that are consistent, reliable, and accurate. The study consists of five sub-tasks.

In order to define the scope of rural and small urban transit facilities, sub-task 1 will involve interviews with practitioners and experts in the field. The objective of sub-task 1 is to understand the typical characteristics of rural and small urban transit facilities. Key information of interest includes the types and sizes of rural and small urban transit facilities, the impact of location characteristics on the design and construction of these facilities, the availability of historical cost data for design and construction of these facilities, and the identification of key estimating items that can influence project costs.

You have agreed to participate in an interview on this subject to be held on DATE and TIME. The following questions will be discussed. The interview should approximately take one hour. The study team thanks you in advance for your participation in this effort.

Interview Questions

1. Please provide a brief description of your experience with rural and small urban transit facilities.
2. In your experience, what are the differences between rural and small urban transit facilities?
3. A classification of rural and small urban transit facilities, based on their functions, is provided below:
 - Operations and Maintenance (Administration, General Purpose, Maintenance and Vehicle Storage)
 - Large Passenger Facilities (Park and Ride, Terminal or Garage and Transit Center)
 - Small Passenger Facilities (Sheltered Bus Stop, Unsheltered Bus Stop and Sign-only Bus Stop)

Are these building types consistent with the transit facilities your organization designs and constructs? Are there other functional types not listed that the team should investigate?

4. How many projects by functional type are typically completed in a year by your agency? (Design, Construction)
5. For each functional type what is the typical:
 - Project size (in units (e.g., square foot) either an average or a range)
 - Project cost (in dollars either an average or a range)

6. What are typical building system components for each type of facility (e.g., beginning from the ground up, foundations, structures, exterior envelope, interior finishes, cooling and heating, and others)?
7. What location characteristics of rural and small urban projects impact the design or construction of these types of projects?
8. What historical cost data does your agency capture from bids or construction to help estimate future design and construction costs on these types of projects?
 - If cost data is captured, does your agency have a database of these costs available and how detailed is the database?
 - Where does the data base reside (field offices or central location)?
9. What are typical risks for these projects by functional type?
10. How are these risks covered in the project estimate and schedule?
11. Do you apply contingencies to design estimates at conceptual, schematic, design development, or construction stages and how is it developed?
12. What is a typical duration of design and construction of these projects by functional type (an average duration or range)?
13. Do you maintain checklists of critical estimate items? Can you share these with us (in writing or anecdotally)?

APPENDIX C

PILOT SURVEY PROTOCOL

Background

Estimating the cost of project design and construction is a challenge. At the same time consistent, reliable, and accurate cost estimates are critically important because agencies (or recipients of Federal funds) use estimates to make key program decisions. Early cost estimates are often the most critical as these estimates support financial decisions to proceed with project design and eventually construction. However, agencies must prepare these estimates when there is limited project scope information.

Our research team is currently studying cost estimation methods for design and construction of rural and small urban transit facilities. This study aims to provide guidance to state transit agencies in assisting their sub-recipients with preparing and/or reviewing the accuracy of design and construction cost estimates. Our goal is to construct an appropriate database of historical cost elements and a standard estimating methodology to assist agencies in developing their cost estimates.

Dr. Stuart Anderson, Texas A&M University, is the Principal Investigator (PI) for this study. **Dr. Keith Molenaar**, University of Colorado, and **Dr. Clifford Schexnayder**, Arizona State University, are the Co-PIs. Our contact information is:

- Dr. Stuart Anderson: 979-845-2407, s-anderson5@tamu.edu,
- Dr. Keith Molenaar: 303-735-4276, keith.molenaar@colorado.edu,
- Dr. Clifford Schexnayder: 202-997-7246, cliff.s@asu.edu.

The research team requests that this questionnaire be completed by **DATE**. The questionnaire is voluntary and research team will hold the data collected in strict confidence as follows:

- Participating in this survey is voluntary.
- The data provided by participants in this questionnaire will be confidential and used only for research purposes.
- Provided data will not be communicated in any form to any organization other than authorized academic researchers and designated staff members working on the project.
- To protect the confidentiality of individuals submitting data, only aggregated data will be presented and published in the report to the National Cooperative Highway Research Program or presentations.

Survey Instruction

This research project focuses on transit facility projects serving rural areas with population of less than 50,000 people and/or small urban areas with population of 50,000 to 199,999 people. These transit facility projects might have one or more of the following functionalities:

- Operations and maintenance facilities (administration, general purpose, maintenance, and vehicle storage),
- Large passenger facilities (park and ride, terminal or garage, transit center, and intercity bus terminal),
- Small passenger facilities (sheltered bus stop, unsheltered bus stop, and sign-only bus stop).

If your agency has constructed any types of the above facilities in the past five years, we do appreciate your participation in this study.

Survey Declaration

⇒ I understand the above information and voluntarily consent to participate in the project entitled NCHRP Project 20-65/Task 53 - Independent Cost Estimates for Design and Construction of Rural and Small Urban Transit Facilities.

Yes

No (Please Cancel the Survey)

⇒ Completion of the following questionnaire requires basic knowledge related to cost estimating practices for rural and small urban transit facility projects. Please select the continue option below if you have this knowledge. If this is not your area of expertise, select the cancel option and kindly forward the questionnaire to an appropriate colleague.

Continue

By selecting continue, I acknowledge that my answers may be anonymously used as part of this study.

⇒ We are asking for your email so we may contact you if we need to clarify your responses and to copy you on the results of this study when completed.

Please do not contact me with the results

I am available for additional questions

Respondent Information

First Name: _____

Last Name: _____

Agency Name: _____

Agency Type:

- Department of Transportation
- Transit Agency
- Consultant
- Other (Please Explain) _____

Organization Unit and/or Job Title: _____

State where you are employed: _____

Email Address: _____

How many years have you been involved with rural and small urban transit facility projects? _____

General Project Information

Project Name: _____

Project Owner(s): _____

Funding Source(s): _____

Primary Designer: _____

Prime Contractor: _____

Project Delivery Method:

- Design-Bid-Build
- Design-Build
- Construction Manager at Risk
- Other (Please Explain) _____

Design Contract Type:

- Lump Sum Contract (based on % of estimated construction costs)
- Unit Price (based on Design Hours times Hourly Rate)
- Cost Plus a Fee
- Incentive Contracts
- Other (Please Explain) _____

Construction Contract Type:

- Unit Price Contract
- Lump Sum Contract
- Cost Plus a Fee
- Incentive Contracts
- Other (Please Explain) _____

Project Construction Location:

- Rural Transit facility (Rural transit projects tend to be relatively small in scope (i.e., often less than \$2,000,000) and located in areas with a population of less than 50,000 people.)
- Small Urban Transit Facility (Urban transit projects often cost more than \$2,000,000 and located in areas with a population of 50,000 to 199,999 people.)
- Urban Transit Facility (Urban transit projects often cost more than \$2,000,000 and located in areas with a population of more than 200,000 people.)

Characteristics of the projects

1. Which of the following classifications best describes the project in question?

(Please select as many as apply.)

- Administration
- Operations
- Maintenance
- Vehicle Storage
- Large Passenger Facilities
- Small Passenger Facility
- Park and ride
- Shelter bus stop
- Un-shelter bus stop
- Sign-only bus stop
- Other (Please Explain) _____

2. What is the total size of the project in square foot (sf)? _____

3. What were the main facility systems and elements? (Please select as many as apply.)

Building Sitework

- Site Preparation
- Site Improvements
- Site Mechanical Utilities
- Site Electrical Utilities
- Other Site Construction

Substructure

- Foundations
- Basement Construction (Basement Excavation, Basement Walls)

Shell

- Super Structure
- Exterior Enclosure
- Roofing

Interiors

- Interior Construction
- Stairs
- Interior Finishes

Services

- Conveying (Elevators & Lifts, Escalators & Moving Walks, Other Conveying Systems)
- Plumbing
- HVAC
- Fire Protection
- Electrical

Equipment & Furnishings

- Equipment
- Furnishings

Special Construction & Demolition

- Special Construction
- Selective Building Demolition
- Other (Please Explain) _____

Cost Estimating

4. What type of historical cost database was used to prepare the cost estimate?

- In-House Database
- Published Database (e.g. RS Means)
- Both In-House and Published Databases
- Cost Data from Similar Projects
- Other (Please Explain) _____

5. Would you share your agency's cost database with us?

- Yes
- No

6. If you are part of Department of Transportation or Transit Agency, do you have a formal process to review the cost estimates prepared by consultants and contractors?

- Yes
- No

7. Please provide the final estimated and actual cost for the design and construction phase of the project.

	Estimated Cost (\$)	Actual Cost (\$)
Design Cost	_____	_____
Construction Cost	_____	_____

8. Please provide the cost percentages of the following construction systems.

	System Cost (%)
Building Sitework (Site Preparation, Site Improvements, Site Mechanical Utilities, Site Electrical Utilities, Other Site Construction)	_____
Substructure (Foundations, Basement Construction)	_____
Shell (Superstructure, Exterior Enclosure, Roofing)	_____
Interiors (Interior Construction, Stairs, Interior Finishes)	_____
Services (Conveying, Plumbing, HVAC, Fire Protection, Electrical)	_____
Equipment & Furnishings (Equipment, Furnishings)	_____
Special Construction & Demolition (Special Construction, Selective Building Demolition)	_____
	100%

9. What method was used to estimate the design cost?

- Similar Projects
- Hours to Design
- Historical Percentage of Construction Cost
- Other (Please Explain) _____

10. What method was used to estimate the Construction cost?

- Similar Projects
- Historical Bid Data
- Other (Please Explain) _____

11. What were the major scope and site related factors that you considered when preparing the estimate for design cost for this project?

12. What were the major scope and site related factors that you considered when preparing the estimate for construction cost for this project?

13. If there were costs overruns for the project, what were the main reasons? If not, what were the success factors?

Schedule

14. Please provide the estimated/actual schedule for the design and construction phase of the project.

	Months	Actual Months
Design Schedule	_____	_____
Construction Schedule	_____	_____

15. Was there any delay in the planning, permitting, design, construction or startup process?

- Yes
 No

16. If yes, what were the main reasons? If not, what were the success factors in this project?

17. What were the major difficulties when developing a schedule for this project?

Risk

18. Was any type of formal risk management process used on this project (e.g., risk identification workshop, maintenance of a risk register, etc.)?

- Yes
 No

19. If yes, please explain how the risk management process supported the cost estimating process.

20. What method was used to estimate the construction contingency?
- Percentage of Construction Cost
 - Review of Project Risks and Bottom-Up Contingency Estimate
 - Other (Please Explain) _____
21. What were the unique risk factors of this project that impacted project cost?

Change Orders

22. Were there any design change orders?
- Yes
 - No
23. If yes, how did the change orders impact design cost? (\$) _____
24. Were there any construction change orders?
- Yes
 - No
25. If yes, how did the change orders impacted construction cost? (\$) _____
26. Were there any disputes and claims in this project?
- Yes
 - No
27. If yes, in which area?
- Construction documents
 - Subsurface conditions
 - Change orders
 - Delays
 - Accelerated Schedules
 - Other (Please Explain) _____

Other

28. Were there any problems with the site conditions of this project?

Yes

No

29. If yes, please explain _____

30. If you could convey one lesson learned about estimating this project to future estimators, what would it be?

31. If possible, please attach the summary of project cost estimate file.

APPENDIX D

THE FIRST ROUND SURVEY PROTOCOL

Background

Estimating the cost of project design and construction is a challenge. At the same time consistent, reliable, and accurate cost estimates are critically important because agencies (or recipients of Federal funds) use estimates to make key program decisions. Early cost estimates are often the most critical as these estimates support financial decisions to proceed with project design and eventually construction. However, agencies must prepare these estimates when there is limited project scope information.

Our research team is currently studying cost estimation methods for design and construction of rural and small urban transit facilities. This study aims to provide guidance to state transit agencies in assisting their sub-recipients with preparing and/or reviewing the accuracy of design and construction cost estimates. Our goal is to construct an appropriate database of historical cost elements and a standard estimating methodology to assist agencies in developing their cost estimates.

Dr. Stuart Anderson, Texas A&M University, is the Principal Investigator (PI) for this study. **Dr. Keith Molenaar**, University of Colorado, and **Dr. Clifford Schexnayder**, Arizona State University, are the Co-PIs. Our contact information is:

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- Dr. Keith Molenaar: 303-735-4276, keith.molenaar@colorado.edu,
- Dr. Clifford Schexnayder: 202-997-7246, cliff.s@asu.edu.

The research team requests that this questionnaire be completed by **DATE**. The questionnaire is voluntary and research team will hold the data collected in strict confidence as follows:

- Participating in this survey is voluntary.
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- Provided data will not be communicated in any form to any organization other than authorized academic researchers and designated staff members working on the project.
- To protect the confidentiality of individuals submitting data, only aggregated data will be presented and published in the report to the National Cooperative Highway Research Program or presentations.

Survey Instruction

This research project focuses on transit facility projects serving rural and/or small urban areas with population of less than 200,000 people. These transit facility projects might have one or more of the following functionalities:

- Operations and maintenance facilities (administration, general purpose, maintenance, and vehicle storage),
- Large passenger facilities (park and ride, terminal or garage, transit center, and intercity bus terminal),
- Small passenger facilities (sheltered bus stop, unsheltered bus stop, and sign-only bus stop).

If your agency has constructed any types of the above facilities in the past five years, we do appreciate your participation in this study.

Survey Declaration

⇒ I understand the above information and voluntarily consent to participate in the project entitled NCHRP Project 20-65/Task 53 - Independent Cost Estimates for Design and Construction of Rural and Small Urban Transit Facilities.

Yes

No (Please Cancel the Survey)

⇒ Completion of the following questionnaire requires basic knowledge related to cost estimating practices for rural and small urban transit facility projects. Please select the continue option below if you have this knowledge. If this is not your area of expertise, select the cancel option and kindly forward the questionnaire to an appropriate colleague.

Continue

By selecting continue, I acknowledge that my answers may be anonymously used as part of this study.

⇒ We are asking for your email so we may contact you if we need to clarify your responses and to copy you on the results of this study when completed.

Email Address: _____

Please do not contact me with the results

I am available for additional questions

Respondent Information

Full Name: _____

Agency Name: _____

Agency Type:

- Department of Transportation
- Transit Agency
- Consultant
- Other (Please Explain) _____

Organization Unit and/or Job Title: _____

How many years have you been involved with rural and small urban transit facility projects? _____

General Project Information

Project Name: _____

Project location (City, State): _____

Start of design (month/year): _____

Start of construction (month/year): _____

Project Owner(s): _____

Funding Source(s):

- Federal program 5309
- Federal program 5310
- Federal program 5311
- Federal program 5316
- Federal program 5317
- The American Recovery and Reinvestment Act's funding
- Funding provided by state DOT
- Other (Please Explain) _____

Project Delivery Method:

- Design-Bid-Build
- Design-Build
- Construction Manager at Risk
- Other (Please Explain) _____

Design Contract Type:

- Lump Sum Contract (based on % of estimated construction costs)
- Unit Price (based on Design Hours times Hourly Rate)
- Cost plus Fee (Cost Reimbursement)
- Incentive Contracts
- Other (Please Explain) _____

Construction Contract Type:

- Unit Price Contract
- Lump Sum Contract
- Cost plus Fee (Cost Reimbursement)
- Incentive Contracts
- Other (Please Explain) _____

Project Construction Location:

- Rural Transit facility (Rural transit projects tend to be relatively small in scope (i.e., often less than \$2,000,000) and located in areas with a population of less than 50,000 people.)
- Small Urban Transit Facility (Urban transit projects often cost more than \$2,000,000 and located in areas with a population of 50,000 to 199,999 people.)
- Urban Transit Facility (Urban transit projects often cost more than \$2,000,000 and located in areas with a population of more than 200,000 people.)

Characteristics of the projects

1. Which of the following classifications best describes the project in question? (Please select as many as apply.)

- Administration
- Operations
- Maintenance
- Vehicle Storage
- Large Passenger Facilities
- Small Passenger Facility
- Park and ride
- Shelter bus stop
- Un-shelter bus stop
- Sign-only bus stop
- Other (Please Explain) _____

2. What is the total size of the project in square foot (sf)? _____

3. What were the main facility systems and elements? (Please select all that apply.)

Building Sitework

- Site Preparation
- Site Improvements
- Site Mechanical Utilities
- Site Electrical Utilities
- Other Site Construction

Substructure

- Foundations
- Basement Construction (Basement Excavation, Basement Walls)

Shell

- Super Structure
- Exterior Enclosure
- Roofing

Interiors

- Interior Construction
- Stairs
- Interior Finishes

Services

- Conveying (Elevators & Lifts, Escalators & Moving Walks, Other Conveying Systems)
- Plumbing
- HVAC
- Fire Protection
- Electrical

Equipment & Furnishings

- Equipment
- Furnishings

Special Construction & Demolition

- Special Construction
- Selective Building Demolition
- Other (Please Explain) _____

Cost Estimating

4. What type of historical cost database was used to prepare the cost estimate?

- In-House Database
- Published Database (e.g. RS Means)
- Both In-House and Published Databases
- Cost Data from Similar Projects
- Other (Please Explain) _____

5. Would you share your agency's cost database with us?

- Yes
- No

6. If you are part of Department of Transportation or Transit Agency, do you have a formal process to review the cost estimates prepared by consultants and contractors?

- Yes
- No

7. Please provide the final estimated and actual cost for the design and construction phase of the project.

	Estimated Cost (\$)	Actual Cost (\$)
Design Cost	_____	_____
Construction Cost	_____	_____

8. Please provide the percentages of construction cost for the following construction systems.

	Construction Cost (%)
Building Sitework (Site Preparation, Site Improvements, Site Mechanical Utilities, Site Electrical Utilities, Other Site Construction)	_____
Substructure (Foundations, Basement Construction)	_____
Shell (Superstructure, Exterior Enclosure, Roofing)	_____
Interiors (Interior Construction, Stairs, Interior Finishes)	_____
Services (Conveying, Plumbing, HVAC, Fire Protection, Electrical)	_____
Equipment & Furnishings (Equipment, Furnishings)	_____
Special Construction & Demolition (Special Construction, Selective Building Demolition)	_____
	100%

9. What method was used to estimate the design cost?

- Similar Projects
- Hours to Design
- Historical Percentage of Construction Cost (What is the percentage? ____%)
- Other (Please Explain) _____

10. What method was used to estimate the Construction cost?

- Similar Projects
- Historical Bid Data
- Other (Please Explain) _____

11. If there were cost overruns for the project, what were the main reasons?

- Environmental issues
- Unexpected underground conditions
- Soil conditions
- Archeological requirements
- Unexpected weather conditions (i.e., snow, hurricanes)
- Increased scope
- Lack of bidding competition
- Bidding time
- Complaint from neighborhood
- Project complexity
- Higher transportation expenses
- Omissions and errors in design
- Other (Please Explain) _____

12. If there were no cost overruns for the project, what were the success factors?

- Hire an experienced construction consultant to perform cost estimating
- Advice from State DOT
- Good weather conditions (i.e., mild winter)
- Good and experienced contractors
- Low project complexity
- No change orders
- No claims and disputes
- Additional funding provided
- Other (Please Explain) _____

Schedule

13. Please provide the estimated/actual schedule for the design and construction phase of the project.

	Estimated Months	Actual Months
Design Schedule	_____	_____
Construction Schedule	_____	_____

14. Was there any delay in the planning, permitting, design, construction or startup process?

- Yes
- No

15. If there was a delay in the planning, permitting, design, construction or startup process, what were the main reasons?

- Funding issues
- Unexpected underground conditions
- Soil conditions
- The duration of environmental approval
- Archeological requirements
- Unexpected weather conditions (i.e., snow, hurricanes)
- Scope creep
- The impact of “Buy America” Act
- Unexpected site conditions
- Complaint from neighborhood
- Lack of expertise
- Omissions and errors in design
- Other (Please Explain) _____

16. If there was no delay in the planning, permitting, design, construction or startup process, what were the success factors?

- Public outreach to avoid community complaints
- Work closely with contractors
- Hire an experienced construction manager to support those processes
- Send for approval ahead of time
- Advice from State DOT (i.e. design prototype documents)
- The transit industrial guidebooks/design prototype
- Good and experienced contractors
- Low project complexity
- No change orders
- No claims and disputes
- Other (Please Explain) _____

17. What were the major difficulties when developing a schedule for this project?

- Funding issues
- Contractors' previous design and construction experience
- Project complexity
- Scope creep
- The impact of "Buy America" Act
- Lack of expertise
- Other (Please Explain) _____

Risk

18. What were the major risk factors of this project?

19. Was any type of formal risk management process used on this project (e.g., risk identification workshop, maintenance of a risk register, etc.)?

- Yes
- No

20. If yes, please explain how the risk management process supported the cost estimating process.

- Risk identification workshops
- Maintenance of risk register
- Risk assessment workshops (both quantitative and qualitative analyses)
- Hire expert modelers
- Risk mitigation workshops
- Other (Please Explain) _____

21. What method was used to estimate the construction contingency?

- Percentage of Construction Cost (What is the percentage? _____%)
- Review of Project Risks and Bottom-Up Contingency Estimate
- Other (Please Explain) _____

Change Orders

22. Were there any design change orders?

- Yes
- No

23. If yes, how did the change orders impact design cost? (\$) _____

24. Were there any construction change orders?

- Yes
- No

25. If yes, how did the change orders impacted construction cost? (\$) _____

26. Were there any disputes and claims in this project?

- Yes
- No

27. If yes, in which area?

- Construction documents
- Subsurface conditions
- Change orders
- Delays
- Accelerated Schedules
- Other (Please Explain) _____

Other

28. If you could convey one lesson learned about estimating this project to future estimators, what would it be?

APPENDIX E

THE SHORTENED SURVEY

Background

Our research team is currently studying cost estimation methods for design and construction of rural and small urban transit facilities. This study aims to provide guidance to state transit agencies in assisting their sub-recipients with preparing and/or reviewing the accuracy of design and construction cost estimates. Our goal is to construct an appropriate database of historical cost elements and a standard estimating methodology to assist agencies in developing their cost estimates.

Dr. Stuart Anderson, Texas A&M University, is the Principal Investigator (PI) for this study. **Dr. Keith Molenaar**, University of Colorado, and **Dr. Clifford Schexnayder**, Arizona State University, are the Co-PIs. Our contact information is:

- Dr. Stuart Anderson: 979-845-2407, s-anderson5@tamu.edu,
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The research team requests that this questionnaire be completed by DATE. The questionnaire is voluntary and research team will hold the data collected in strict confidence as follows:

- Participating in this survey is voluntary.
- The data provided by participants in this questionnaire will be confidential and used only for research purposes.
- Provided data will not be communicated in any form to any organization other than authorized academic researchers and designated staff members working on the project.
- To protect the confidentiality of individuals submitting data, only aggregated data will be presented and published in the report to the National Cooperative Highway Research Program or presentations.

Survey Instruction

This research project focuses on transit facility projects serving rural and/or small urban areas with population of less than 200,000 people. These transit facility projects might have one or more of the following functionalities:

- Operations and maintenance facilities (administration, general purpose, maintenance, and vehicle storage),
- Large passenger facilities (park and ride, terminal or garage, transit center, and intercity bus terminal),
- Small passenger facilities (sheltered bus stop, unsheltered bus stop, and sign-only bus stop).

If your agency has constructed any types of the above facilities in the past five years, we do appreciate your participation in this study.

⇒ We are asking for your email so we may contact you if we need to clarify your responses and to copy you on the results of this study when completed.

Email Address: _____

- Please do not contact me with the results
- I am available for additional questions

Respondent Information

Full Name: _____

Agency Name: _____

Agency Type:

- Department of Transportation
- Transit Agency
- Consultant
- Other (Please Explain) _____

Organization Unit and/or Job Title: _____

How many years have you been involved with rural and small urban transit facility projects? _____

General Project Information

Project Name: _____

Project location (City, State): _____

Project Owner(s): _____

Funding Source(s):

- Federal program 5309
- Federal program 5310
- Federal program 5311
- Federal program 5316
- Federal program 5317
- The American Recovery and Reinvestment Act's funding
- Funding provided by state DOT
- Other (Please Explain) _____

Design Contract Type:

- Lump Sum Contract (based on % of estimated construction costs)
- Unit Price (based on Design Hours times Hourly Rate)
- Cost plus Fee (Cost Reimbursement)
- Incentive Contracts
- Other (Please Explain) _____

Construction Contract Type:

- Unit Price Contract
- Lump Sum Contract
- Cost plus Fee (Cost Reimbursement)
- Incentive Contracts
- Other (Please Explain) _____

Project Construction Location:

- Rural Transit facility (Rural transit projects tend to be relatively small in scope (i.e., often less than \$2,000,000) and located in areas with a population of less than 50,000 people.)
- Small Urban Transit Facility (Urban transit projects often cost more than \$2,000,000 and located in areas with a population of 50,000 to 199,999 people.)
- Urban Transit Facility (Urban transit projects often cost more than \$2,000,000 and located in areas with a population of more than 200,000 people.)

Characteristics of the projects

1. Which of the following classifications best describes the project in question? (Please select as many as apply.)

- Administration
- Operations
- Maintenance
- Vehicle Storage
- Large Passenger Facilities
- Small Passenger Facility
- Park and ride
- Shelter bus stop
- Un-shelter bus stop
- Sign-only bus stop
- Other (Please Explain) _____

2. What is the total size of the project in square foot (sf)? _____

3. What were the main facility systems and elements? (Please select all that apply.)

Building Sitework

- Site Preparation
- Site Improvements
- Site Mechanical Utilities
- Site Electrical Utilities
- Other Site Construction

Substructure

- Foundations
- Basement Construction (Basement Excavation, Basement Walls)

Shell

- Super Structure
- Exterior Enclosure
- Roofing

Interiors

- Interior Construction
- Stairs
- Interior Finishes

Services

Conveying (Elevators & Lifts, Escalators & Moving Walks, Other Conveying Systems)

- Plumbing
- HVAC
- Fire Protection
- Electrical

Equipment & Furnishings

- Equipment
- Furnishings

Special Construction & Demolition

- Special Construction
- Selective Building Demolition
- Other (Please Explain) _____

Cost Estimating

4. What method was used to estimate the design cost?

- Similar Projects
- Hours to Design
- Historical Percentage of Construction Cost (What is the percentage? ____%)
- Other (Please Explain) _____

5. What method was used to estimate the Construction cost?

- Similar Projects (if No please skip question #6)
- Historical Bid Data (if Yes please answer question #6)
- Other (Please Explain) _____

6. What type of historical cost database was used to prepare the cost estimate?

- In-House Database
- Published Database (e.g. RS Means)
- Both In-House and Published Databases
- Cost Data from Similar Projects
- Other (Please Explain) _____

7. If you are part of Department of Transportation or Transit Agency, do you have a formal process to review the cost estimates prepared by consultants and contractors?

- Yes
- No

8. Please provide the final estimated and actual cost for the design and construction phase of the project (gross number).

	Estimated Cost (\$)	Actual Cost (\$)
Design Cost	_____	_____
Construction Cost	_____	_____

9. If there were cost overruns for the project, what were the main reasons?

- Environmental issues
- Unexpected underground conditions
- Soil conditions
- Archeological requirements
- Unexpected weather conditions (i.e., snow, hurricanes)
- Increased scope
- Lack of bidding competition
- Bidding time
- Complaint from neighborhood
- Project complexity
- Higher transportation expenses
- Omissions and errors in design
- Other (Please Explain) _____

10. Please provide the percentages of construction cost for the following construction systems.

	Construction Cost (%)
Building Sitework (Site Preparation, Site Improvements, Site Mechanical Utilities, Site Electrical Utilities, Other Site Construction)	_____
Substructure (Foundations, Basement Construction)	_____
Shell (Superstructure, Exterior Enclosure, Roofing)	_____
Interiors (Interior Construction, Stairs, Interior Finishes)	_____
Services (Conveying, Plumbing, HVAC, Fire Protection, Electrical)	_____
Equipment & Furnishings (Equipment, Furnishings)	_____
Special Construction & Demolition (Special Construction, Selective Building Demolition)	_____
	100%

Schedule

11. Start of design (month/year): _____

12. Completion of design (month/year): _____

13. Start of construction (month/year): _____

14. Completion of construction (month/year): _____

Risk

15. What were the major risk factors of this project?

16. What method was used to estimate the construction contingency?

Percentage of Construction Cost (What is the percentage? _____%)

Review of Project Risks and Bottom-Up Contingency Estimate

Other (Please Explain) _____

Other

17. If you could convey one lesson learned about estimating this project to future estimators, what would it be?

APPENDIX F

LOCATION ADJUSTMENT FACTOR

Table 10 shows location adjustment factors calculations for ten regions.

Table 10 Location Adjustment Factors

	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

Table 10 Continued

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
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

Table 10 Continued

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
	Somersets	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

Table 10 Continued

Tennessee	Memphis	655,155	87.8
	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

Table 10 Continued

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
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

Table 10 Continued

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
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
	Berkeley	112,580	117.2
	Stockton	291,707	108.6
California	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

Table 10 Continued

	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

3

³ The population statistics (2010) were obtained from the lists of cities of the U.S. at Wikipedia.com

APPENDIX G

TOOL REVIEW PROTOCOL

As part of National Cooperative Highway Research Program (NCHRP) project 20-65, Task 53, this research focuses on the development of “Independent Cost Estimates for Design and Construction of Rural and Small Urban 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 facilities. It should also assist transit operators when they apply for funds from 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 us your suggestions on revising the tool by answering the following questions. It would be appreciated if you can send us your feedback by DATE

Again, the research team thanks you for your time and feedback in advance.

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, and
- 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 suggestion and instruction concerning the contingency setting are helpful?

4. Do you think the estimates report clearly shows you 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 here.

5. Do you think the Estimates Details section is helpful for you to understand the adjustment factors and calculations of the construction and design costs? If there was any cause for confusion, please list your suggestions for correcting the situation below.

6. If more actual cost data is 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 below.

APPENDIX H

COST ESTIMATING PROCESS

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

Table 11 Steps of Cost Estimating Process

Cost Estimation Step	Description
Determine Estimate Basis	Document project type and scope, including <ul style="list-style-type: none">• 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 <ul style="list-style-type: none">• 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 <ul style="list-style-type: none">• project knowns and unknowns,• potential risks associated with these uncertainties, and• appropriate level of contingency congruent with project risks.

Table 11 Continued

<p>Review and Approve Estimate</p>	<p>Review estimate basis and assumptions, including</p> <ul style="list-style-type: none"> • 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. <p>Approve estimate include</p> <ul style="list-style-type: none"> • 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.
<p>Determine Estimate Communication Approach</p>	<p>Communication approach is dependent upon the stakeholder who is receiving the information, but should consider</p> <ul style="list-style-type: none"> • 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.