Cost Estimating Tool for Early Estimates for Rural and Small Urban Transit Facilities

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ABSTRACT

Construction cost overruns in many small projects can lead to program overruns and hence be just as problematic as a large overrun on a single project. Since there is a lack of compiled cost information or databases to support estimation of rural and small urban transit facilities, this paper focuses on cost estimation and risk assessment for design and construction of rural and small urban transit facilities. The goal of this paper is to define the characteristics of rural and small urban transit facilities, identify and assess their typical risk factors, and develop a database and tool to support conceptual estimating process for these facilities. Initially, this work reviewed the existing literature and described the characteristics of rural and small urban transit facilities. Next, telephone interviews of DOT staff, consultants, and transit managers were conducted and analyzed. Later, based on the literature review and telephone interviews, survey questions were developed and distributed to collect specific historical design and construction costs data. Regression models were generated to predict project design and construction costs based on the size of these types of facilities. The typical risk factors associated with these projects were identified and their frequency levels determined. The final product of the work was development of a cost estimating tool for rural and small urban transit facilities.

Keywords: Rural Transit Facilities, Small Urban, Cost Estimation, Risk Assessment, Project Characteristics
INTRODUCTION
Rural and small urban transit facility projects are relatively limited in scope and dollar value, but they are numerous, and geographically dispersed. It is difficult to estimate the design and construction costs for such projects because of:

- Variations in facility function and project size;
- Different amenities associated with the facilities;
- Often involves the renovation of existing facilities;
- Lack of historical cost data;
- Unique risk factors impacting cost (e.g. remote location or lack of competition); and
- Agency lack 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 (1, 2). Recent research specific to rural projects (3) addressed issues such as construction administration, engineering, operation, and safety; but does not cover cost estimating processes and methodologies for rural transit projects.

More specifically, there is a lack of 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 facilities. Second, the functions and scopes of these facilities vary considerably. Third, the facilities can involve new facilities but correspondingly the project may a renovation and improvement of facilities used previously for other purposes. Last, rural transit projects tend to receive funding from many different sources and the funds are administered by different agencies. Frequently, each agency requires the expenditure of funds to follow different cost management procedures.

OBJECTIVE
The main objectives of this work for the American Association of State Highway Transportation Officials (AASHTO) Standing Committee on Public Transportation were to define the characteristics of rural and small urban transit facilities, identify and assess typical risk factors associated with these types of projects, develop an appropriate cost database of historical relevant cost elements, and create a tool to support conceptual estimating process for these facilities. This paper describes:

- Current estimating practices for small transit facilities; and
- Creation of a regression model to predict project design and construction costs for such facilities.

LITERATURE REVIEW
According to the definition given by the Federal Transit Administration (FTA) (4), 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 areas are outside of metropolitan
areas and the population is less than 50,000 people. Hallowell et al. (5) considered rural as areas with a population of less than 50,000 people. Hallowell’s 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.

According to the Texas Rural Transportation Plan (6), transit facilities are categorized into three major groups:

1. Operations and Maintenance: (Administration, General Purpose, Maintenance and 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)

The resource Architectural and Engineering Design for a Transit Operating and Maintenance Facility (7), also known as Recommend Practice, includes the steps necessary to implement a new bus transit facility project. In this Recommend Practice, facility types are classified as:

- **Level I**: As primary service facility providing running maintenance and storage.
- **Level II**: Secondary maintenance facility is often called an inspection garage.
- **Level III**: Third level maintenance facility provides all other kinds of vehicle maintenance.

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 (8). 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 (9). The scope of facility projects can vary greatly, from low-cost repairs, ramps, or signs to major intermodal facilities in urban locations (10).

The Rural Transit Program Manual (11) was developed to assist rural transit services. The manual discusses the determination of the need for rural transit and rural transit facilities’ implementation, use, maintenance, and operation. The Rural Transit Program Manual states that design costs are normally limited to six percentage of the estimated construction cost.

**RESEARCH METHODOLOGY**
The logic of how the research was conducted is shown in Figure 1. A five-step methodology was used:

1. Review of recently designed and constructed rural and small urban transit facilities;
2. Interview process;
3. Survey data collection;
4. Data analysis; and
5. Develop a cost estimating methodology/tool to support conceptual estimating.

**FIGURE 1 Research Process**

**RESEARCH HYPOTHESES**

The researchers tested two research hypotheses:

1. A larger rural or small urban transit facility requires more design cost; and
2. A larger facility requires more construction cost.

**INTERVIEW PROCESS**

A telephone interview protocol was developed to understand the characteristics of rural and small urban transit facilities. Six individuals, including three DOT personnel, two consultants, and one transit manager, participated in the interview. These professionals were located in different regions in the United States. Before the interview, a project memorandum and a list of questions were sent to the interviewees so they were prepared for the discussions. The duration of each interview was about one hour and included thirteen questions covering five areas of interest:
• Difference 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; and
• Typical risk factors and contingency estimation.

INTERVIEW RESULTS
The interview results cover the following seven aspects:

1. 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 for these facilities. 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.

2. 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. Table 1 shows the size range of different types of facilities.

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Size Range (sf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration</td>
<td>2,500 - 3,000</td>
</tr>
<tr>
<td>Operation and Maintenance</td>
<td>8,000 - 13,000</td>
</tr>
<tr>
<td>Bus Shelter</td>
<td>50 - 150</td>
</tr>
<tr>
<td>Vehicle Storage</td>
<td>8,000 - 12,000</td>
</tr>
<tr>
<td>transit complex (including administration, storage, and garage)</td>
<td>12,000 - 20,000</td>
</tr>
</tbody>
</table>

3. 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).

In general, 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 on the west coast. The cost
range of a para-transit facility\(^1\) is 12 to 16 million dollars. Table 2 shows unit cost of different types of facilities.

**TABLE 2 Unit Cost of Transit Facilities**

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration</td>
<td>$150-$200/square foot</td>
</tr>
<tr>
<td>Operation and Maintenance</td>
<td>$300/square foot (the cost depends on what kind maintenance service is performed.)</td>
</tr>
<tr>
<td>Open Bus Storage</td>
<td>$125-$250/square foot</td>
</tr>
</tbody>
</table>

4. **The Availability of Historical Cost Data**

It seems that 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 consultant cost databases are used by the consultant estimators.

5. **The Availability of Checklist of Critical Estimate Items**

Cost engineers in consulting firms often 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 and track reasons behind delays and cost overruns.

6. **Typical Risk Factors**

According to the interviewees, the typical risk factors associated with rural and small urban transit facilities include at least the following items.

- Soil conditions: unexpected soil conditions such as contaminated soil may be found in rural and small urban areas.
- Unexpected underground features: underground in the area of these projects may contain buried debris and utilities, which were not previously identified.
- Neighborhood complaints: major complaints concerning noise and dust control can cause a lengthy construction delay.
- Increased scope: continuous incrementally changes in project scope increase project cost.

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\(^1\) Para-transit is an alternative mode of flexible passenger transportation that does not follow fixed routes or schedules.
Higher transportation expenses: because these projects are in remote areas, they need to pay more travel time.

Lack of competition: project cost is often raised due to lack of competition (i.e., the number of bidders per project).

Funding availability: construction of rural transit facilities is often delayed because of funding constraints.

Archaeological impact: if relics are found on the site, construction is often suspended until relics are protected or removed.

7. Contingency Estimation

Contingency is set according to project type, size, location, and project characteristics. However, sometimes the contingency is not sufficient to cover all the unknown factors, such as weather conditions, soil conditions, site location, or needed change orders. According to the interviewees from state DOTs, 10 to 15 percent of construction cost is often suggested as an appropriate contingency. It should be noted that this percentage should change with the information available and the scope of design that is complete when the contingency is assigned.

SURVEY DATA COLLECTION

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

- Size and type of facilities
- Different facilities features
- Locations of facilities
- Actual design and construction costs
- Design and construction schedule
- Project risks
- Change orders
- Major facilities component costs of construction

The pilot survey protocols were sent initially 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 tool was developed. Potential participants included state DOTs’ program managers, transit managers, and consultants. Including four pilot surveys, there were 26 survey respondents.

SURVEY DATA ANALYSIS

Initially, all design and construction cost data was normalized by performing the following two steps. First, all actual design and construction cost data were adjusted from various locations to
national average costs by using the City Cost Index in R.S. Means Building Construction Cost Data manual based on the following equation:

\[
\text{Specific City Cost} \times 100
\]

\[
\frac{\text{City Index Number}}{\text{Specific City Cost}} \times \text{City Index Number}
\]

Then, the national average costs were adjusted from any previous years to 2014 using the Historical Cost Index in the manual. The equation for this adjustment is as follows:

\[
\frac{\text{Index for Year A}}{\text{Index for Year B}} \times \text{Cost in Year B} = \text{Cost in Year A}
\]

Survey results indicated that most of the design costs of those projects were estimated by using similar projects. Therefore, regression analysis was performed to identify the relationship between the design/construction cost of rural and small urban transit facilities and project size. The regression plots and statistical summaries are shown in Figure 2.

**FIGURE 2 Regression Plot: Project Size vs. Design and Construction Cost**

The R square for trend line showing the relationship between project size and design cost is 0.91, this indicates a straight line regression model is a good predicting model for rural and small urban transit facilities design cost. Moreover, the R square for regression model predicting the relationship between project size and construction cost is 0.94, which indicates the regression model can be used to calculate rural and small urban transit facilities construction cost based on the project size.
Based on the statistical analysis, the p-value for the relationship between design/construction versus project size is <0.0001 (at 90% confidence level) and therefore, there is a linear relationship between project size and design/construction cost. This means the larger the rural and small urban transit facility size; the project requires more design/construction cost.

**Risk Analysis**

The frequency of the risk factors stated by survey participants is shown in Figure 3. Soil conditions and unexpected underground conditions are the most frequent risk. Contaminated soil, buried debris, and unexpected utilities can increase project cost and also cause unanticipated delay during construction.

Although some respondents suggested different risk factors in the survey, their projects did not experience cost overruns. This might be to their initial estimates including sufficient contingency.

![Frequency of Risk Factors](image)

**Contingency Estimating**

Based on the survey results, 21 out of 26 respondents stated they used a percentage of construction cost to estimate contingency. Contingency percentages provided by the respondents ranged from 4% to 15%. The average contingency is 9.5%, and median of contingency is 10%.
COST ESTIMATING TOOL DEVELOPMENT

The types of rural and small urban transit facilities include administration, operation, maintenance, vehicle storage, park and ride, sheltered bus stop, un-sheltered bus stop, and sign-only bus stop. The historical cost data collected to develop the database in support of this tool covers only those facilities in the administration, operations, maintenance, and vehicle storage types due to incomplete data concerning the last four types.

The cost estimating tool was developed in MS Excel and consists of five tabs: Introduction; User’s Guide; Project Information; Estimates Report; and Estimates Details.

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

User’s Guide Tab: 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 cost estimating experts.

In the 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 project cost. 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.

Project Information Tab: 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 capture of this tab is shown in Figure 4.
FIGURE 4 Screen Capture of the Cost Estimating Tool – Project Information

**Estimates Report Tab:** 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 earlier. The sum of base construction cost and contingency comprises a total construction cost. Screen capture of the Estimates Report for ABC example project is shown in Figure 5.
Estimates Details Tab: 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 capture of this tab for ABC example project is shown in Figure 6.
LIMITATIONS

The cost estimating database and tool only support conceptual estimating during the schematic development phase. Both the cost estimating database and 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 the rural and small urban areas in the last five years.
- Majority of the potential survey participants provided by the RTAP were state DOTs personnel and transit managers. Many seem to lack the cost estimating knowledge to complete the survey or historical data is simply not retained.
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 tool can be improved by performing further larger scale of data collection. Design consultants and contractors would be another source for historical cost data.

CONCLUSIONS AND RECOMMENDATIONS
This research focused on cost estimating methods and database development for costing design and construction of Rural and Small Urban Transit Facilities which are usually small, numerous, and geographically dispersed. 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 tool. The general conclusions about Rural and Small Urban Transit Facilities cost estimation include:

- Project design and construction costs depend on various factors, such as facility types, project size, location, and facility features.
- State DOTs and transit agencies rely primarily on the estimates prepared by consultants and 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 tool to predict future design and construction costs at 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 and survey results provided reference on determining the default contingency range for cost estimating tool.

For future studies, it is recommended to target a greater number of practitioners with cost estimating expertise who are involved in rural and small urban transit facility projects. Second, as an alternative to collecting cost data through a survey, a Delphi process could be performed. Third, cost and schedule impacts of each risk factor should be asked in the survey so risk factors can be quantified, and thereby risk analysis and management for rural and small urban transit facilities could be better structured.

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