A Tool to Select Road Maintenance Contracting Methods

Kishor SHRESTHA¹, M.S.C.M., E.I.T. and Pramen P. SHRESTHA², Ph.D., P.E

¹ Ph. D. Student, Department of Civil and Environmental Engineering and Construction, Howard R. Hughes College of Engineering, University of Nevada, Las Vegas, 4505 S. Maryland Parkway, Las Vegas, NV 89154, USA; E-mail: shrest11@unlv.nevada.edu

² Associate Professor, Department of Civil and Environmental Engineering and Construction, Howard R. Hughes College of Engineering, University of Nevada, Las Vegas, 4505 S. Maryland Parkway, Las Vegas, NV 89154, USA; E-mail: pramen.shrestha@unlv.edu

ABSTRACT
In every Department of Transportation (DOT), the majority of the budget is expended in maintaining roads, bridges, and interchanges. Generally, three types of road maintenance methods are used: In-House, Method-Based Contract (MBC), and Performance-Based Contract (PBC). Numerous research reports are available to assist DOT maintenance engineers or managers to choose a suitable road maintenance method for their typical maintenance activities. However, these engineers do not have time to go through the bulky reports and guidelines to choose an appropriate maintenance contracting method. The purpose of this study was to develop a stand-alone software tool to assist DOT maintenance engineers and managers choose the best method for road maintenance activities. Further, this study synthesized several relevant literatures in order to develop criteria for the selection methods. A literature review was conducted to identify the criteria for selecting the methods. The software tool based the selection of methods on a decision-tree diagram. Using this software, the user is able to print out the decision suggested by the software tool, a personal description of the user, project description, and the questions attended by the user. Recommendations regarding the use of this tool and suggestions for further study are discussed.

Keywords: In-House, Method-Based Contract, Performance-Based Contract, Decision-Tree Diagram, Software Tool.

INTRODUCTION
In 2013, the United States allocated $74 billion for new construction and maintenance of the transportation systems (USDOT 2013). For the maintenance of their road systems, Nevada Department of Transportation (NDOT) allocated 14.4% of its total budget in 2012 (Office of Management and Budget 2012 and NDOT 2012). Basically, Departments of Transportation (DOTs) use three kinds of maintenance methods: 1) In-House or State Force, 2) Prescriptive-Based Contracts or Method-Based Contracts (MBC), and 3) Output-Based Contracts or Performance-Based Contracts (PBC). For a particular road-maintenance activity, the selection of those methods depends on various factors, including:
1. Availability of staff in the DOTs;
2. Degree of schedule complexity of the work in the DOTs;
3. Requirements for specific knowledge, expertise, or skill;
4. The need to save money or time;
5. The contractors’ capability to perform the projects;
6. Life-cycle cost considerations;
7. Requirements for state statutes;
8. Types of maintenance activities or the suitability of maintenance activities to put into a package;
9. Willingness of DOTs transfer risk to the contractor;
10. The requirement of a minimum level of service (LOS); and

In the first method, the In-House method, DOT uses its own staff and equipment as well as purchases the required maintenance materials for a project. This method is strongly recommended for some typical road maintenance activities, for example, activities that need emergency response, such as snow removal, application of anti-skid and/or de-icing material in the winter, and small-scale works (NCHRP 2009 and Ribreau 2003).

The second method, MBC, generally is used for all kinds of out-sourcing of tender works. In this method, the lowest-bid contractor wins the contract; this contractor uses prescribed specifications, and operates within the limitations of “what to do,” “when to do,” and “how to do” (Stankevich et al. 2009). The MBC method is suitable when state DOTs either do not have sufficient work force, have time constraints, need to save money, or have a lack of expertise for a specific type of work, such as bridge maintenance works (NCHRP 2003). In the United States, the use of MBC was significantly increased, more than 50%, since the 1990s (NCHRP 2003). Payment to the contractor in this method is based on the measurement of work and the contractor’s bid rate with satisfactory work completion, according to the specification.

The third method, PBC, was used first in British Columbia, Canada in 1988 to maintain a road network (Zietlow 2004). In this method, generally, the ‘best-value’ method is used to select a contractor; both the contract bid cost and the technical qualifications are considered. The state DOTs look for the work outputs rather than for work inputs, that is, “what to do,” “when to do,” and “how to do” (Stankevich et al. 2009). Transportation agencies choose the PBC method to transfer their risks to the PBC contractor and to save money (Zietlow 2004, Zietsman 2004, NCHRP 2003, NCHRP 2009). Payment to the contractor is done on a monthly basis under the compliance of performance targets.

In order to help them choose the right contracting method for a road maintenance activity, many guidelines and research reports are available to DOT project managers. However, because of time constraints, it has been impossible to read all the reports or guidelines to select the right method. In general, the DOT road-maintenance managers often choose a method based on their experiences rather than
assessing all the possible methods and using the most suitable method for a particular project. Therefore, this study developed a stand-alone software tool to assist the DOT maintenance managers and engineers choose the best method to complete road maintenance activities easily, simply, and with reliable results.

BACKGROUND

Menches et al. (2010) synthesized a number of studies regarding innovative contracting strategies used for routine and preventive maintenance contracts in the U.S. Their study concluded that cost savings was one of the main factors that inspired the state DOTs’ managers to choose out-sourcing. The other factors were government directives, trying to achieve a higher level of service (LOS), and a lack of expertise among DOT personnel because of staff retirements. The authors also considered the following to select a particular type of specification: ease of defining measurable performance criteria of the maintenance activities, risk transfer to the contractor, management of particular administrator team for a Performance-Based specification contract, and requirements of a warranty for the contractor’s work.

The authors described three primary types of contract specifications for out-sourcing (Segal et al. 2003). The three types of contract specifications are traditional or MBC, PBC, and warranty contract specifications. Moreover, the study introduced a ‘hybrid method,’ a combination of multiple types of contract specifications.

The authors also described a number of reasons that prompted state DOT project managers to call private contractors for road maintenance (Segal et al. 2003). Basically, the main reasons that influenced the DOT managers to out-source were to reduce costs, increase efficiency, improve quality, increase the LOS, speed up the project delivery, spur innovation, enhance risk management, overcome a lack of expertise, and to keep legislative mandate. The study also pointed out that after the federal government passed the Transportation Equity Act for the 21st Century (TEA-21), a majority of the states began out-sourcing a huge number of road maintenance work. Moreover, the study developed a framework for the selection of decision criteria. These included the number of activities to out-source, the name of the activities to out-source, the name of activities to be bundled, selection of delivery methods for an individual activity, selection of delivery methods for bundled activities, selection of delivery methods for nearly all activities, selection of type of contract specifications, and selection of pricing strategy.

Another study synthesized the out-sourcing practices of the state DOTs in the U.S., and summarized reasons why the agencies made the decision to out-source the road maintenance works (NCHRP 2003). This study conducted a questionnaire survey with the state DOT employees, and summarized the major reasons behind out-sourcing the road maintenance contracts: availability of staffing; a construction cost threshold of $5 million; the complexity of the work/time schedule; expertise in a particular maintenance activity, such as bridge maintenance; lack of resources; and to save money. In the survey, only 6% of the DOT personnel responded that cost-effectiveness influenced the decision to choose out-sourcing.

This particular study synthesized the reasons behind the state DOTs choosing the PBC method as well as advantages and disadvantages of this method (NCHRP 2009). Basically, the PBC method focuses on the work output or performance quality
of the contractor. This method offers both incentives and disincentives according to the quality of work output of the contractor; in addition, payments are based on the contractor’s performance quality. The advantages of the PBC method are cost savings, better LOS, risk transfer from the DOT to the contractor; and innovation. The disadvantages of this method are a longer procurement process, less competition among contractors, and loss of control towards the maintenance work and flexibility.

This study also collected the reasons that DOT personnel chose the PBC method, which included increasing and fixing the LOS; decreasing the DOT’s total cost, transferring the risk from the DOT to the contractor, setting a fixed budget for long-term future maintenance, and minimizing the life-cycle cost of the maintenance works. The study described various kinds of PBC methods, which were chosen depending upon certain conditions, for example single activity, single asset, a set of related activities, corridor, area-wide, hybrid, agency-to-agency, warranty-based, and multi-phase. A single activity type was selected when there was only one activity to be maintained, such as rest area maintenance. The single asset type was selected for more than one activity; however, the activities were related with each other, such as different activities involved in bridge maintenance. The corridor type consists of all the activities within a boundary of a road, such as all the road maintenance activities in between fence-to-fence. The hybrid is a combination of more than one specification, for example, a combination of MBC and PBC, because some activities are maintained according to the MBC method and others according to the PBC method.

**METHODOLOGY AND PROCESS FLOW MODEL**

This study developed a stand-alone software tool for DOT managers or engineers to choose the most suitable contracting method of road maintenance. The software tool, which uses Visual Studio 2012, primarily is based on a decision-tree analysis, as shown in Figure 1. It is clear that the flowchart diverts the method of road maintenance, that is, whether it should be done by an In-House method or outsourcing methods. If outsourcing is selected, then the flow chart diverts again in order to decide whether MBC or PBC should be selected.

Basically, there are three primary methods of road maintenance: In-House, MBC, and PBC. The literatures showed that state DOTs chose those three methods of road maintenance in different circumstances. In other words, different criteria of each maintenance work influence the state DOT project managers to choose different methods of road maintenance.

In addition to the literature review to determine the criteria for selecting methods of road maintenance, this study conducted a questionnaire survey with 50 DOTs and the District of Columbia. The questionnaire survey consists of a couple of questions regarding the reasons for selecting In-House, MBC, and PBC.
Figure 1. A decision-tree diagram to choose road maintenance methods
Table 1 shows a summary of the criteria to select methods for road-maintenance contracting. The In-House method is suitable mostly for emergency works and small scope works. MBC and PBC methods are suitable when DOT suffers from a lack of workforce and resources or when the maintenance work is large-scale in terms of cost and project scope. Specifically, the PBC method is suitable for a long-term contract, when transfer of risk from the DOT to the contractor is required, and to fix or increase the LOS for a continuous, long duration. The selection of the methods is described by the Decision Tree flowchart in Figure 1.

Table 1. Criteria to Select the Suitable Road Maintenance Contracting Methods

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Methods of Road Maintenance</th>
<th>Criteria for Selecting Methods</th>
</tr>
</thead>
</table>
| 1    | In-House                    | ▪ Emergency works (snow removal, anti-icing, and de-icing)  
                             | ▪ Small-scope work            
                             | ▪ Enough staffing, equipment, required expertise, and no schedule complexity |
| 2    | MBC                         | ▪ Large-scale work in terms of cost and scope  
                             | ▪ Lack of expertise, staff, equipment, and other resources in the state DOTs  
                             | ▪ Schedule complexity         
                             | ▪ To speed up the work completion |
| 3    | PBC                         | ▪ Willingness to transfer risk to the contractor  
                             | ▪ Enough funds available for a longer duration (more than three years)  
                             | ▪ A need to maintain a minimum LOS for a long duration  
                             | ▪ Maintenance activities are easily put into a package or bundle  
                             | ▪ Cost effectiveness while considering the life-cycle cost |

Based on the above criteria, first of all, the flowchart decides whether the maintenance work should be maintained by the In-House method. Basically, the In-House method is selected in two cases. First, if the maintenance work is emergency work, for example, snow removal in the winter season. Second, if the activity to be maintained satisfies four conditions: the DOT has sufficient resources and expertise to maintain the activity, the work is not schedule driven, the activity is not of large scope in terms of cost and scope, and the road length is not greater than 1500 miles. Otherwise, an out-sourcing method is selected. When an out-sourcing method is selected, two methods can be chosen, MBC or PBC. The PBC method is selected if either of the Questions 6 to 9 in Figure 1 is marked as ‘Yes’ – is there long-term funding available in the DOT, the DOT wants to transfer the risk to the contractor, the
activities to be maintained can be bundled, and the DOT seeks to minimize the LOS for a long time. If not, the MBC method is selected. The detailed methodology is described in Figure 1.

PROGRAM DEVELOPMENT

This program is a stand-alone software or desktop application, a user can use it on any windows computer independently. For simplicity, the program execution is divided into three parts: general information, attending questions, and show result. In the first, the program asks the user to fill up the personal and project information, such as name of the project, name of the road, county, mileage, and name of the user. When the user presses the ‘Next’ button at bottom right, the program pop-ups a new decision analysis page; however, if the user did not fill up all the information in the general information page, a warning message pops up to suggest that the user fills in all the information. Figure 2 shows a snapshot of the general information page.

![General Information Page](image)

**Figure 2. A software tool to select the most suitable method of road maintenance**

In the second part, the program displays questions one at a time; there are nine questions altogether. Each question is ‘Yes’ and ‘No’ types, and the user required to check one button either ‘Yes’ or ‘No’. When the user clicks the ‘Next’ button, the program shows another question. The program displays questions until the users’ attempt is sufficient to decide which contracting method is the most suitable one to maintain the given activity. As shown in Figure 1, sometimes the user does not need to answer all the nine questions to get a decision because some questions trigger the program to make a decision straightaway. For example, the program chooses the In-House method for all emergency works.

In the last part, according to the users’ responses to the questions, the program gives a result whether to use the In-House, MBC, or PBC method. In the result, the
program shows the personal and project information that was given in the first part as well as the responses to questions with ‘Yes’ or ‘No’ answers and the date and time the program was used. Moreover, the user can print the results for their files. The ‘Print Report’ button appears when the program gives result. Figure 3 shows a snapshot of this second stage as well as a result at the end of the program.

![Decision Analysis](image)

**Figure 3. The software tool’s results, which can be printed out**

**CONCLUSIONS AND RECOMMENDATIONS**

This paper developed a stand-alone software tool to assist DOT road maintenance engineers to select the best method of their road maintenance activities. The selection criteria of the road maintenance decision-tree analysis are developed based on relevant literatures and survey responses of the questionnaire survey, and then were programmed to develop a software tool. Because the responses to the questionnaire survey still are being collected; once a sufficient number of responses are received, the criteria will be included fully in this study. By the application of the software, the user is able to make decisions and make print outs of the decision
suggested by the software tool, a personal description of the user, project description, and the questions attended by the user. The authors also recommend incorporating life cycle cost analysis data in this software while making decision on a suitable road maintenance contracting method.

ACKNOWLEDGEMENT

The authors would like to thank Nevada Department of Transportation for funding the study on road maintenance contracting methods. The research project number is P017-12-803.

REFERENCES


