Best-Value Model Based on Project Specific Characteristics

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Abstract: Best-value becomes a well known procurement practice in many states in the country. The objective of this transformation from the old practice of lowest bid to best-value is to increase the value added to the project for each dollar added. This paper discusses a new concept of best-value modeling that is unique and tailored to each project. The model uses records of past projects to obtain specific evaluation criteria, from which a best-value score is determined for each contractor. Primary parameters that impact contractor selection are identified and analyzed based on which best-value model is designed. Data are collected from groups of experts in the Minnesota Department of Transportation. Two application methods are used to assess the best-value: (1) the weighted average method; and (2) the analytic hierarchy process. Although the paper is written to assist government agencies in selecting the best contractor(s), the research results shared in this paper are relevant to both academics and practitioners. The paper provides practitioners with a tool for ranking contractors based on best-value and provides academics with selection parameters, a model to evaluate this best-value, and a methodology of quantifying the qualitative effect of subjective factors.

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Introduction

Many agencies from federal and state levels are adopting best-value procurement. Best-value aims at enhancing the long-term performance through selecting the contractor with the offer most advantageous to the owner where price and other selection factors are considered. Factors other than price can vary, but they typically include technical and managerial merit, financial health, and past performance (Gransberg and Ellicott 1996, 1997; Gransberg and Senadheera 1999; Gransberg et al. 2006). The inclusion of key factors that match the specific needs of a project increases the possibility of selecting the best contractor for the project. The NCHRP 10-61 research study (Scott et al. 2006) shows an increasing trend in the construction sector toward the use of various best-value procurement methods. A long-standing concern expressed by government agencies is that low-bid, while promoting competition, and a fair playing field may not result in the best-value for dollars expended or the best performance during construction. As noted by Scott et al. (2006), the low-bid system encourages contractors to implement cost-cutting measures instead of quality enhancing measures and therefore makes it less likely that contracts will be awarded to the best-performing contractors who will deliver the optimum quality projects. However, the research revealed that federal agencies have moved aggressively toward the use of best-value procurement, have attempted to measure its relative success, and are convinced that it achieves better results than low-bid.

The best-value system is viewed as a balance between the consideration of price and qualifications. Several studies showed that best-value is useful for the owner and the project due to the following reasons:

- The low-bid method fails to serve the public interest because the lowest offer may not result in the lowest overall cost to the public (FAR 2005).
- A reduction in cost growth from 5.7 to 2.5% and a reduction in claims and litigation by 86% (NAVFAC 1996).
- The General Services Administration Public Building Services procures 100% of its new buildings and renovations through best-value procurement.
- A 1997 National Science Foundation study concluded that design-build contracts procured using the two-step best-value procurement procedure had the best cost and schedule growth performance, albeit representing a very small average improvement over the other procurement methods (Scott et al. 2005).
- The best-value procurement was emerging as a viable alternative to traditional low-bid method in the public sector construction, and practitioners need to be prepared for this emerging trend (Vacura and Bante 2003).

Considering Project Specific Characteristics

The NCHRP 10-61 research study recommends few basic strategies to implement in the area of best-value procurement starting from legislative guidelines to model specifications and including industry collaboration. A research shortage is noticed in relating project characteristics with parameters, which should be a base in the contractor selection process. Therefore, the aim of this study is to establish a flexible model capable of being tailored to the

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specific project needs. This flexibility will be obvious in the selection of parameters, to be included in the contractor selection process, and in the determination of the parameter's weights. The establishment of the best-value model calls the past record of the contractor work for the agency as an indicator of his qualification trend.

The goal for a best-value selection is to obtain the optimum combination of price and technical capabilities of a contractor. When used correctly, a best-value selection rewards those who propose innovative concepts that enhance product quality or lower the price of quality. Owners may introduce inappropriate biases into the selection process or add cost to the procurement. They must think carefully of what is "valuable" in the product and not just "important" or "required" in the selection process. Using technical, managerial, or performance elements that are of indeterminate value, while important or required, simply clouds the decision. Owners should base best-value selection criteria only on project elements that add measurable value to the project (Molenaar and Johnson 2003). State agencies agree that the right choice of the evaluation factors that assess the competitors and their relevant weights is the core of a successful best-value procurement system. Agencies view best-value as one solution that combines the advantages of innovative contracting methods (Office of Construction and Innovative Contracting 2005). Suggested evaluation factors and implementation steps for best-value are those considered in earlier innovative contracting methods.

Innovative Contracting Methods

The literature search for innovative contracting methods revealed eight different types, which could be listed as (Office of Construction and Innovative Contracting 2005): (1) A+B bidding; (2) lane-rental; (3) incentives/disincentives; (4) liquidated savings; (5) no-excuse bonus; (6) design-build; (7) pay-for-performance; and (8) warranties. Three of the stated methods consider parameters, in the contractor selection process, which are similar to the utilized ones in the best-value model. The A+B bidding reduces contract time on projects. Contractors bid the time to complete the project and a dollar amount for work items. The contract is awarded to the lowest combination of time and cost. Although, this method improves coordination between prime and subcontractors and minimizes impacts to users, it may require more resources for contract administration and more intense negotiations for additional work (Office of Construction and Innovative Contracting 2005). Lane-rental bidding reduces impacts on the traveling public by minimizing the time of lane closure. Contractors are charged a fee for closing lanes and shoulders due to construction activities. The concept focuses on the delay time for public, not the overall contract time. Lane rentals encourage contractors to minimize road-user impacts and enhance coordination of prime and subcontractors, and it requires extra effort to monitor lane rental and add potential costs to the project (Office of Construction and Innovative Contracting 2005).

A warranty method requires contractors to guarantee all or portions of a construction project to be free of defects, in materials and workmanship, for a period of time. The contractor is required to correct deficiencies that occur during the warranty period. The length of warranty period varies from project to the other, probably 2–3 years for transportation projects. Warranty decreases inspection level allowing the state to allocate resources elsewhere. Owner must ensure that warranty guidelines are reasonable and enforceable.

Best-Value Model Concepts

The term best-value has many competing definitions in the industry. One of the suggested broad definitions of best-value is "A procurement process where price and other key factors are considered in the evaluation and selection process to enhance the long-term performance and value of construction" (Scott et al. 2006). This definition was disaggregated into four primary concepts; Parameters, evaluation criteria, rating systems, and award algorithms. Based on the analysis of the literature, meetings, and case studies, it is declared that a best-value procurement that is simple to implement and flexible to adjust to the project specific characteristics is the most effective approach in the context of a traditional bidding system.

Model Parameters

The parameters and evaluation criteria of best-value are first determined from literature, surveys, case studies, and meetings. A preliminary list of evaluation criteria, as shown in Table 1, is prepared and the proposed measurement of each evaluation criteria is suggested. Based on previous the applications of best-value model within the department of transportations (DOTs), it is suggested that evaluation criteria should be less in number and easy to obtain from project records. The research team discussed the possibility of including each evaluation criterion in the conceptual model. A final list of evaluation criteria and suggested measurement factors is shown in Table 2. The research team had two concerns in finalizing the list of evaluation criteria; keeping the model as easy to use as possible by reducing the number of criteria and overcoming any lack of familiarity of DOT officials and contractors with best-value environment as a relatively new concept.

Parameter Importance

The first parameter selected to be included in the model is bid price. This parameter was the most important parameter in selecting contractors using the traditional procurement system. For public agencies, lowest bid selection is enforced by law. Contract time is used as a competitive parameter in contracts that require a fast track. This parameter represents the (B) part in the A+B bidding process which yields from contract time multiplied by road-user cost. The third included parameter is warranty (WR), which is a pertinent factor with the amount of the risk a contractor would take. WR is included as the number of warranty years guaranteed by the contractor. The next parameter is lane rental (LR) which reflects the impact of construction activities on the road users' time and money. LR is equal to the percentage of lane closure estimated cost divided by the total bid amount. Past quality is a record parameter that shows the quality of final product where it is evaluated by the percentage of rejected test specimens divided by the total test specimens. Employees parameter is evaluated by the degree of compliance with the requirements of both the equal employment opportunity (EEO) and the federal disadvantaged business enterprise program. Claims parameter indicates the cooperation of the contractor with the owner. This parameter is measured by the percentage of the record rejected claims divided by the total bid amount in millions of dollars.

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Table 1. Total Collected Best-Value Parameters and Corresponding Measures

Parameters	Evaluation criteria	Subfactors	Proposed measures
Cost	Initial capital cost	Construction cost	Bid price
		Procurement cost	
		Design cost (DB projects)	
	Life cycle cost	Life-cycle cost	Life cycle cost
Time	Time to build project	Design time (DB projects)	Design time (DB projects)
		Construction time	Construction time
	Lane rental	Total road user cost	Lane closure cost according to schedule
	Traffic control	Effect of lane closure on road users' time due to road diversion	Cost of road diversion on total daily traffic
Qualification and performance	Prequalification	Financial information	Number of years in business
		Cooperation	Commercial license
		Bonding requirements	Previous owners
	Past project performance	Overall past project success	Number of completed projects within last years
		Past schedule performance	Safety record
		Past quality performance	History of timely delivery
	Personnel experience	Relevant technical experience	License and registration Past project experience of individual
	Project management plan	Relevant experience	Relevant experience of project personnel
		Proposed schedule/work plan	Plan for logistics as material and equipment
		Subcontracting plan	Workman's compensation insurance modifier as measure of safety records
		Key personnel plan	
		Safety plan	
Quality	Warranty	Construction warranty	Warranty time
	Quality management plan	Quality control plan	Construction engineer inspection
	Quality parameters	Quality control measurements for material and workman ship	Test results Percentage rejected specimens
Design alternates	Proposed design alternates	Alternative material or technology and work innovation	Determined by MN/DOT
	Technical proposal responsiveness	Compliance with specification and requirements	Determined by MN/DOT
	Environmental consideration	Aesthetics	Regulation and requirements must be met

Model Development

The general equation for best-value is shown as follows:

$$\mathrm{BV}_j = \sum_{i=1}^{n} \mathrm{PS}_i W_i \tag{1}$$

Where BV_j=best-value for contractor j; n=number of parameters included in the best-value equation; PS_i=parameter i scale; and W_i=weight of parameter i.

There are two schools of thoughts in determining the values of parameter scale (PS_i) and weight (W_i). In the first one, Option I, the parameter scale (PS_i) reflects the value of the performance level of best-value parameter as it exists for a specific contactor and project. The weight (W_i) reflects parameter's importance relative to the other parameters irrespective of any particular contactor or project. The value for W_i is a fixed part of the BV_j formula and does not change with the project type or contractor because it represents the relative importance of each parameter to the others. Consequently, project type does not affect this relative importance because it is a generic weight (not project or contractor specific). For example, if warranty is not included in a project, then the value of (PS_i) equals to zero. However, W_i has a value relative to the other parameters irrespective to project characteristics. Then, for this parameter, the value of $\mathrm{BV}_j=\mathrm{PS}_i * W_i=\text{zero} * \text{value} = \text{zero}$.

In the second one, Option II, both (PS_i) and (W_i) reflect project specifics where both of them are sensitive to any project characteristics. For example, if warranty is not included in a project, then the value of (PS_i) and (W_i) are equal to zero. Then, for this parameter, the value of $\mathrm{BV}_j=\mathrm{PS}_i * W_i=\text{zero} * \text{value}=\text{zero}$.

The difference between Option I and Option II is that the first generates lower values for BV_j, which is more conservative than the latter. Most likely, both options result in similar decisions (i.e., the list of ranked contractors is similar). The detailed description of both options is shown in the following sections.

Parameters Scale (PS_i)

The parameters of each project are identified and their scales are calculated and normalized on a scale of 0–100 using the following steps:

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Table 2. Final Selected Parameters for Best-Value Model

Evaluation parameters	Definition
BP=bid price	Bid amount as finally agreed upon with the owner
CT=contract time	Contract time for current project
WR=warranty	Warranty years guaranteed as offered by the contractor
UT=unauthorized time	Average unauthorized delay time that is recorded for past contractor performance
CL=rejected claims	Average rejected claims that is recorded for past contractor performance
PQ=quality	Average quality that is recorded for past contractor performance
LR=lane rental cost	Average recorded lane rental cost
TC=traffic control	Average recorded traffic control compliance for past contractor performance
EM=employees	Average adherence to EEO and DBE requirements for past contractor performance

1. Determine the value of each parameter using the following equations:

$$\text{Contract time:} \quad \text{CT} = \text{Number of days bid} * \text{Daily user cost} \tag{2}$$

$$\text{Unauthorized time: UT} = \left(\sum \frac{\text{Unauthorized delay time}}{\text{Total project duration}} \right) \% \tag{3}$$

$$\text{or} \quad \text{UT} = \left(\sum \frac{\text{Liquidated damage amount}}{\text{Total \$ bid amount}} \right) \% \tag{4}$$

$$\text{Rejected Claims: CL} = \left(\sum \frac{\text{Number of rejected Claims}}{\text{Total \$ million bids}} \right) \% \tag{5}$$

$$\text{Quality:} \quad \text{PQ} = \frac{\text{Rejected test specimens}}{\text{Total tested specimens}} \% \tag{6}$$

$$\text{Lane rental cost: LR} = \left(\sum \frac{\text{Lane rental rate} \times \text{hours bid}}{\text{Total \$ million bids}} \right) \% \tag{7}$$

$$\text{Traffic Control: TC} = \left(\sum \frac{\text{\$ Amount for noncompliance}}{\text{Total \$ million bids}} \right) \% \tag{8}$$

2. Determine the best and worst values for each parameter from among the available contractor values.
3. Assign a PS_i ranging from 1 to 100 to each contractor parameter value using

$$\text{Parameter scale (PS}i) = \frac{\text{best parameter value}}{\text{contractor value}} \times 100 \tag{9}$$

4. The contractor that has the best parameter value will get PS = 100.
5. The contractor with the worst parameter value has PS_i equals to one. The value of one (small number) is elected to avoid any mathematical flaw in the scale implementation.

Parameters Weight (W_i)

The next step is to obtain the relative weights (W_i) for each included parameter in the best-value model. The total summation of parameters' weight should be equal to 1. These weights are determined based on the opinion of DOT experts. Two methods are used to determine the value of relative weights (W_i): (1) weighted average method (WAM); and (2) analytic hierarchy process (AHP). The following sections are depicting these methods.

Weighted Average Method

The steps of WAM implementation can be summarized as follows:

1. A questionnaire is sent to district engineers to rate the significance of each parameter in the BV equation using a scale of 1–5 in which 1=maximum significance; 2=high significance; 3=low significance; 4=minimum significance; and 5=not significant.
2. Assign weight scale equal to 100 and 1 for the rating equals to 1 and 5, respectively. The following equation is used to assign weights for the remaining rates on the scale:

$$\text{Weight scale} = \left(1 - \frac{\text{rate} - 1}{5 - 1}\right) \times 100 \tag{10}$$

3. The results are a weight scale equals to 75, 50, and 25 for rates 2, 3, and 4, respectively.
4. Calculate the summation of weights for BV parameters.
5. Calculate the relative weight (W_i), ranging from 0 to 1, of each parameter to the summation of weight for all parameters. The total summation of relative weights must equal to 1.

Analytic Hierarchy Process

Analytic hierarchy process is an easy mature technique that attempts to simulate human decision process (Saaty 1991). It allows decision-makers to incorporate both qualitative and quantitative considerations of human thought and intuition. Several steps are required to model a problem using AHP method as follows (Saaty 1982,1991):

1. A set of factors that contribute to problem solving should be identified. Then, these identified factors will be categorized within a hierarchy of various levels. In the best-value problem, the factors are listed in Table 2.
2. Thus, the relative weights of these factors are obtained using pairwise comparison matrices. These matrices are collected from District Engineers, which grasp their opinion regarding the above-mentioned factors (Table 2). Using mathematical processes (eigenvalue and vector determination), factors' weights can be determined. Each factor weight represents the relative importance of this factor among the others.
3. In order to consider the resulted weights from a pairwise comparison matrix, the logical consistency of weights has to be verified based on the matrix consistency ratio (C.R.). If the C.R. is more than 10%, then the results are inconsistent.

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Determine the importance of the following factors in the selection of the
most suitable contractor for your project:
(Assign 1= maximum Significance, 2= high Significance, 3= low Significance,
4= minimum Significance, and 5= not Significance at all,)
1. Wining bid to be the lowest bid:
     o1          o2          o3          o4          o5
2. Completing the project with no delay:
     o1          o2          o3          o4          o5
3. Increasing the warranty years of the project:
     o1          o2          o3          o4          o5
4. Reducing number of claims:
     o1          o2          o3          o4          o5
5. Final product to be of high quality:
     o1          o2          o3          o4          o5
6. Lane rental cost by the contractor:
     o1          o2          o3          o4          o5
7. Contractor compliance with traffic control:
     o1          o2          o3          o4          o5
8. Contractor adherence to EEO and DBE requirements:
     o1          o2          o3          o4          o5
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Fig. 1. Evaluation parameters importance questionnaire

Hence, the assigned priority values should be modified until the C.R. value is verified. The C.R. value can be determined using the following equations (Saaty 1982,1991; Zayed and Halpin 2004):

$$\mathrm{CI} = \frac{\lambda_{\max} - m}{m - I} \tag{11}$$

$$\mathrm{C.R.} = \mathrm{CI}/\mathrm{RI} \tag{12}$$

where CI=matrix consistency index; m=matrix size; $\lambda_{\max}$=maximum eigenvalue; RI=random index [it has a value related to the matrix size (Saaty 1982)].

Best-Value Determination

After determining the value of PS_i and W_i, both values are multiplied in order to determine the best-value for each parameter. Then, Eq. (1) will be implemented where the best-values of parameters are added to constitute the final best-value score for each contractor. Contractors will be sorted based on the best-value in which the contractor of highest best-value score is the winner.

Model Implementation

To demonstrate the best-value model working, real-world data are collected. These data include a group of two pilot projects (two case studies) is identified to be used in the test-drive process of the model. The chosen group represents two different project scenarios in order to test values result from model application. Both are different in volume, location, scope, preferences, and work type. For both pilot projects, calculations are made for the lowest three bidders through the following stages:

1. Determination of PS_i;
2. Determination of Wi; and
3. Determination of best-value.

Data for the two case studies are collected from the Minnesota Department of Transportation (MnDOT). In addition, subjective data are collected from district engineers through a questionnaire.

Data Collection

TH-113 Project

The primary purpose of this project is to reclaim state highway TH-113 (Mahnomen County, Minn.) from the junction of TH 32 to the Norman/Mahnomen County line. District 4 out of Detroit Lakes added a 1.5 in. (3.75 cm) overlay from Norman/Mahnomen County line to city of Waubun (Mahnomen County is in District 4). The project also includes extending centerline RCP culverts to improve safety. The goal of this project is to extend the life of TH-113 for 12 to 15 years of the current expected life. This project is detoured with 35 working days assigned for contract completion. This contract was let in January 2006 with an Engineering estimate of \$2,084,814 and a bid price of \$2,155,015.

Table 3. Values of Model Parameters for Both Pilot Projects

		TH-494			TH-113		
Parameters	Units	Bidder A	Bidder B	Bidder C	Bidder A	Bidder B	Bidder C
BP=bid price	(millions)	9.9	10.12	10.19	2.15	2.26	2.36
CT=contract time	(millions)	1	0.9	1.35	N/A	N/A	N/A
WR=warranty	(years)	N/A	N/A	N/A	N/A	N/A	N/A
UT=unauthorized time	%	0.01	0.02	0	6	7	0
RC=rejected claims	%	20	26	15	0	25	40
PQ=quality	%	2	3	1	15	12	0
LR=lane rental cost	%	2.9	2.5	3.6	N/A	N/A	N/A
TC=traffic control	%	0.05	0.08	0.04	0.1	.05	0
EM=employees	%	3	3	5	4	2	3

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TH-494 Project

This project is a new Valley Creek Road interchange with interstate I-494 in Woodbury, Minn. The project includes grading, concrete and bituminous surfacing, and signal system. This project is detoured with 145 working days assigned for contract completion. This contract was let in April 2006 with an Engineering estimate of \$ 9,059,490 and a bid price of \$ 9,932,277

Questionnaire

A questionnaire is used with the district engineers to encompass their subjective opinion regarding the parameters' weight as shown in Fig. 1. The engineers are asked to evaluate the significance of parameters using a scale from 1 to 5, where 1 represents the maximum significance and 5 is not significant. The collected data from these questionnaires are used to develop the parameters' weight. Fourteen groups of District engineers are asked to answer the questionnaire questions. Each group consists of the District engineer and the other engineers in his/her office. All groups answered the questionnaire with a 100% response rate.

Determination of Parameter Scale (PS_i)

The parameters of each project are first identified and their related data for different bidders are collected as shown in Table 3. Next, the values of parameters are normalized on a scale of 0–100 using the above-mentioned steps. The value of each parameter is calculated using Eqs. (2)–(8) for each contractor. For example, quality parameter for TH-113 can be calculated for Bidder A using

$$\mathrm{PQ} = \frac{\text{Rejected test specimens}}{\text{Total tested specimens}}\,\%$$

$$\mathrm{PO}_A = 15\% \tag{13}$$

Similarly, the quality parameters for Contractors B and C is 12 and 0%, respectively. The bidder that has the best parameter scale value will get PS=100. The value PS = 0, however, will be replaced with a small number to avoid eliminating the scale. This relation assumes a linear relation between the parameter and the scale as shown in Fig. 2. The values of parameter scale (PS_i) for various contractors in both projects (TH-113 and TH-494) are shown in Table 4. It shows the PS_i values for all bidders where Bidder C has various areas of excellence in unauthorized time, quality, and traffic control in both projects. However, Bidder B in TH-113 project has only one area of excellence (i.e., employees). The other bidders have moderate values of PS_i.

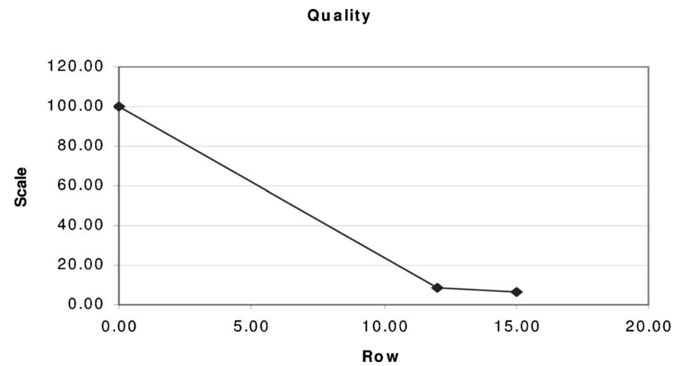

Fig. 2. Relation between value of parameters and parameters scale

Determination of Parameter Weights (W_i)

Weighted Average Method

The next step is to obtain the relevant weights for each included parameter in the best-value model. The weights are determined based on questionnaire results. Assign weight scale equal to 100 and 1 for the rating equal 1 and 5, respectively. Eq. (10) will be applied to calculate the weight as shown in Tables 5 and 6 for Options I and II, respectively. Table 5 illustrates the weight (W_i) values using both methods WAM (Option I) and AHP (Options I and II). It shows, in the first column, the average rating of various parameters based on the 14 groups of experts. In the second column, these average rates are transferred to rates out of 100 based on the scale that is explained in Eq. (10). In the third column, the relative weights (W_i) are calculated for each parameter. It is noticed that the weights do not reflect the parameters that are not included in the project. They are determined based upon Option I school of thought. It is also noted that bid price, contract time, unauthorized time, quality, and employees have the highest weight (0.15) among other parameters.

Table 6 demonstrates Option II application using the WAM in which the weight (W_i) reflects project characteristics. It shows that traffic control has the highest weight in TH-113 project with approximately 7.2% increase above bid price importance. However, bid price, contract time, and unauthorized time have the highest weight of 0.17 in TH-494 project. Employees' parameter has the lowest weight of 0.063 and 0.05 for TH-113 and TH-494 projects, respectively. It is noted that warranty is not included in both projects.

Table 4. Parameters Scale (PS_i) for Contractors in Case Study Projects

	Parameter scale (PS_i)—TH-113			Parameter scale (PS_i)—TH-494		
Parameters	Bidder A	Bidder B	Bidder C	Bidder A	Bidder B	Bidder C
BP=bid price	100.00	95.13	91.10	100.00	97.83	97.15
CT=contract time	N/A	N/A	N/A	90.00	100.00	66.67
WR=warranty	N/A	N/A	N/A	N/A	N/A	N/A
UT=unauthorized time	1.67	1.43	100.00	50.00	25.00	100.00
RC=rejected claims	100.00	4.00	0.25	75.00	57.69	100.00
PQ=quality	6.67	8.33	100.00	50.00	33.33	100.00
LR=lane rental cost	N/A	N/A	N/A	86.21	100.00	69.44
TC=traffic control	10.00	20.00	100.00	80.00	50.00	100.00
EM=employees	50.00	100.00	66.67	100.00	100.00	60.00

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Table 5. Weight (W_i) of Parameters

Parameters	WAM—Option I			Analytic hierarchy process—weight (W_i)		
	Average rating	Rating scale	Relative weight (W_i)	Option I	Option II—TH-113	Option II—TH-494
BP=bid price	3	50	0.15	0.10	0.15	0.11
CT=contract time	3	50	0.15	0.13	N/A	0.15
WR=warranty	4	25	0.08	0.10	N/A	N/A
UT=unauthorized time	3	50	0.15	0.12	0.19	0.15
RC=rejected claims	5	1	0.00	0.10	0.14	0.10
PQ=quality	3	50	0.15	0.12	0.18	0.13
LR=lane rental cost	4	25	0.08	0.11	N/A	0.12
TC=traffic control	4	25	0.08	0.10	0.15	0.11
EM=employees	3	50	0.15	0.12	0.19	0.13
	Sum	326	1.00	1.00	1.00	1.00

Analytic Hierarchy Process

The above-mentioned steps of applying the AHP technique are carried out in order to generate the parameters' weights. Pairwise comparison matrices are analyzed for both Options I and II. In Option I, the matrices have dimensions 9×9; however, in Option II, they are 6×6 and 8×8 for TH-113 and TH-494 projects, respectively. The C.R. for Option I matrix is 0.0199 (less than 0.1), which means it is a consistent matrix and the weights of this matrix are justifiable and valid. Table 5, the Fourth column, shows the values of these weights that result from the AHP technique application in Option I. It is noted that contract time has the highest weight (0.13) and bid price has the lowest weight of 0.10.

Similarly, the C.R. value of Option II matrices for TH-113 and TH-494 projects are 0.021 and 0.0192 (less than 0.1), which are acceptable. The weights for best-value parameters in Option II using the AHP technique are shown in Table 5, the fifth and sixth columns, for TH-113 and TH-494 projects, respectively. It is noted that contract time and unauthorized time have the highest weight (0.15) and rejected claims has the lowest weight of 0.10.

Determination of Best-Value

Weighted Average Method

Finally, the BV is calculated, using Eq. (1), as shown in Tables 7 and 8 for Options I and II, respectively. Table 7 shows the best-value, using Option I, for both projects (TH-113 and TH-494). The numbers in Table 7 are calculated by multiplying the parameter scale (PS_i) in Table 4 by the weight (W_i) values in Table 5, the third column for all bidders. It is noted that Bidder C has the highest best-value, 62.54 and 78.30, in TH-113 and TH-494 projects, respectively. Similarly, using Option II, the best-value is calculated, as shown in Table 8, by multiplying the weights in Table 6 by the corresponding parameter scales in Table 4. It is also noted that bidder C has the highest best-value, 85.32 and 87.88, in TH-113 and TH-494 projects, respectively. It is obvious that Options I and II result in similar decisions (i.e., Bidder C is has the highest best-value), which disagrees with the lowest bid (Bidder A). However, Option I is more conservative than Option II because it always has lower best-value. Both options result in similar rank for contractors (i.e., Bidders C, A, then, B). The case is different in TH-113 project where Bidder B has a higher best-value than Bidder A in Option I.

Analytic Hierarchy Process

Similarly, the best-value is calculated, using AHP method, as shown in Tables 9 and 10 for Options I and II, respectively. Table 9 shows the best-value, using Option I, for both projects (TH-113 and TH-494). The numbers in Table 9 are calculated by multiplying the numbers in Table 4 by the weight values in Table 5, the Fourth column, for all bidders. It is noted that Bidder C has the highest best-value, 50.46 and 77.45, in TH-113 and TH-494 projects, respectively. Similarly, using Option II, the best-value is calculated, as shown in Table 10, by multiplying the weights in Table 5, the fifth and sixth columns, by the corresponding parameter scales in Table 4. It is also noted that Bidder C has the highest best-value, 78.14 and 85.76, in TH-113 and TH-494

Table 6. Option II—Weight (W_i) of Parameters Using WAM

Parameters	TH-113 Project			TH-494 Project		
	Rating	Rating scale	Weight (W_i)	Rating	Rating scale	Weight (W_i)
BP=bid price	3	50	0.125	1	100	0.17
CT=contract time	1	N/A	N/A	1	100	0.17
WR=warranty	4	N/A	N/A	4	N/A	N/A
UT=unauthorized time	1	100	0.25	1	100	0.17
RC=rejected claims	3	50	0.125	3	50	0.09
PQ=quality	1	100	0.25	2	75	0.13
LR=lane rental cost	2	N/A	N/A	2	75	0.13
TC=traffic control	2	75	0.197	3	50	0.09
EM=employees	4	25	0.063	4	25	0.05
	Sum	400	1.00	Sum	575	1.00

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Table 7. Best-Value for Option I Using the WAM

Parameters	Best-value TH-113 Bidder A	Bidder B	Bidder C	Best-value TH-494 Bidder A	Bidder B	Bidder C
BP=bid price	15.34	14.59	13.97	15.34	15.00	14.90
CT=contract time	N/A	N/A	N/A	13.80	15.34	10.23
WR=warranty	N/A	N/A	N/A	N/A	N/A	N/A
UT=unauthorized time	0.26	0.22	15.34	7.67	3.83	15.34
RC=rejected claims	0.31	0.01	0.00	0.23	0.18	0.31
PQ=quality	1.02	1.28	15.34	7.67	5.11	15.34
LR=lane rental cost	N/A	N/A	N/A	6.61	7.67	5.33
TC=traffic control	0.77	1.53	7.67	6.13	3.83	7.67
EM=employees	7.67	15.34	10.23	15.34	15.34	9.20
Best-value=	25.36	32.97	**62.54**	72.79	66.31	**78.30**

projects, respectively. This result does not agree with the low-bid system as the lowest bid was for Bidder A. It is obvious that both Options I and II result in similar decisions (i.e., Bidder C is has the highest best-value); however, Option I is more conservative than Option II because it always has lower best-value. Both options result in similar rank for contractors (i.e., Bidders C, A, then, B).

Comparing Results of the AHP and WAM Methods

Both methods have shown similar trends and close values as shown in Tables 7–10. They result in similar decisions where Bidder C has the highest best-value in both projects. However, the results of the AHP method are more consistent in ranking bidders than the WAM because there is no conflict in the rank of bidders between different options (I and II). It is also obvious that the best-values for Options I and II are closer to each other in TH-494 project. This is because the only missed parameter in this project is warranty. However; there are three parameters missed in TH-113 project, warranty, contract time, and lane rental cost. Therefore, the difference between Options I and II best-values are larger in the TH-113 project. Both methods reach the same conclusion.

The significance of best-value system in this case is that the owner has the ability to select the Bidder that best fits the project needs. Moreover, the owner, if legislatively approved, could select a contractor that bid higher but has an advantage to optimally

Table 8. The Best-Value for Option II Using the WAM

Parameters	Best-value TH-113 Bidder A	Bidder B	Bidder C	Best-value TH-494 Bidder A	Bidder B	Bidder C
BP=bid price	12.50	11.89	11.39	17.00	16.63	16.52
CT=contract time	N/A	N/A	N/A	15.30	17.00	11.33
WR=warranty	N/A	N/A	N/A	N/A	N/A	N/A
UT=unauthorized time	0.42	0.36	25.00	8.50	4.25	17.00
RC=rejected claims	12.50	0.50	0.03	6.75	5.19	9.00
PQ=quality	1.67	2.08	25.00	6.50	4.33	13.00
LR=lane rental cost	N/A	N/A	N/A	11.21	13.00	9.03
TC=traffic control	1.97	3.94	19.70	7.20	4.50	9.00
EM=employees	3.15	6.30	4.20	5.00	5.00	3.00
Best-value=	32.21	25.07	**85.32**	77.46	69.91	**87.88**

Table 9. Best-Value for Option I Using the AHP

Parameters	Best-value TH-113 Bidder A	Bidder B	Bidder C	Best-value TH-494 Bidder A	Bidder B	Bidder C
BP=bid price	9.50	9.04	8.66	9.50	9.30	9.23
CT=contract time	N/A	N/A	N/A	12.06	13.40	8.93
WR=warranty	N/A	N/A	N/A	N/A	N/A	N/A
UT=unauthorized time	0.20	0.17	11.93	5.97	2.98	11.93
RC=rejected claims	10.47	0.42	0.03	7.86	6.04	10.47
PQ=quality	0.83	1.03	12.42	6.21	4.14	12.42
LR=lane rental cost	N/A	N/A	N/A	9.27	10.75	7.46
TC=traffic control	0.96	1.91	9.57	7.66	4.79	9.57
EM=employees	6.19	12.38	8.25	12.38	12.38	7.43
Best-value=	28.15	24.96	**50.86**	70.90	63.77	**77.45**

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Table 10. Best-Value for Option II Using the AHP

Parameters	Best-value TH-113			Best-value TH-494		
	Bidder A	Bidder B	Bidder C	Bidder A	Bidder B	Bidder C
BP=bid price	14.92	14.19	13.59	11.06	10.82	10.75
CT=contract time	N/A	N/A	N/A	13.19	14.65	9.77
WR=warranty	N/A	N/A	N/A	N/A	N/A	N/A
UT=unauthorized time	0.32	0.28	19.34	7.33	3.66	14.65
RC=rejected claims	14.12	0.56	0.04	7.67	5.90	10.23
PQ=quality	1.18	1.47	17.69	6.65	4.43	13.29
LR=lane rental cost	N/A	N/A	N/A	10.42	12.08	8.39
TC=traffic control	1.46	2.92	14.58	8.52	5.32	10.65
EM=employees	9.67	19.34	12.90	13.38	13.38	8.03
Best-Value=	41.67	38.76	**78.14**	78.21	70.26	**85.76**

construct the project. In addition, the proposed best-value model can also help selecting a lowest bidder with best qualifications for the project. A low-bid agency may use best-value as part of the lowest bid practice to select a contractor for a job in case two or more low proposals are very close in their bids. In this scenario, the weight of the bid price would be set higher compared to other parameters and the resulting best-value is controlled by bid price. The MnDOT engineers suggest 75–80% weight for the bid price (i.e., 20–25% to all other combined parameters) in order to adopt this scenario in the transition period.

Sensitivity Analysis

As mentioned, the relative weight of price parameter is obtained form a questionnaire. However, that is not the only way to obtain the weight. Owners may prefer to fix the price parameter relative weight at some desired level based on historic experience or other reasons. A sensitivity analysis was suggested to investigate the effect of changing the price parameter relative weight from 0, no price parameter considered in contractor selection, to 100, only the bid price is considered in the selection process (traditional method). The sensitivity analysis is also supposed to show the relative weight of price parameter at which price has an effect equal to other qualification parameters, which is the intersection point between the lowest bid line and highest qualification bid. The sensitivity analysis for both projects is shown in Figs. 3 and 4. For project TH-113, up to a price parameter relative weight of 0.86 the selected contractor is Contractor C, which has the highest qualification parameter. Increasing the relative weight of price parameter more than 0.86 will result in the selection of the best contractor to go to Bidder A with the lowest bid price. Similarly, the diversion point for TH-494 occurs when the relative weight of price parameter is ≤0.82 as shown in Fig. 4.

Summary and Conclusions

Best-value contracting strategy aims at using price and other key factors in the evaluation and selection process to enhance the long-term performance of projects. The inclusion of key factors that match the very specific needs of a specific project guarantees that the selected contractor is the best to construct the facility. Previous attempts to implement best-value contracting strategy did not consider the unique characteristics of each construction project. The current study, unlike previous studies, deals with each project as unique and so considers the appropriate parameters to be included in the contractor selection process.

The aim was to establish a flexible model capable of being

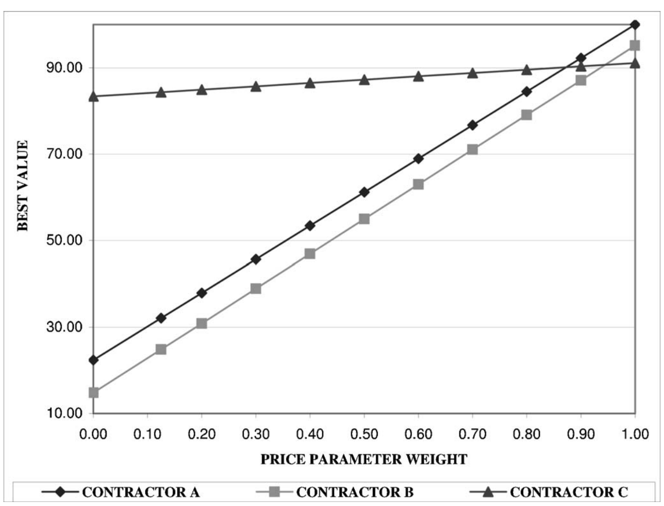

Fig. 3. Sensitivity analysis of change of best-value versus price parameter relative weight for TH-113

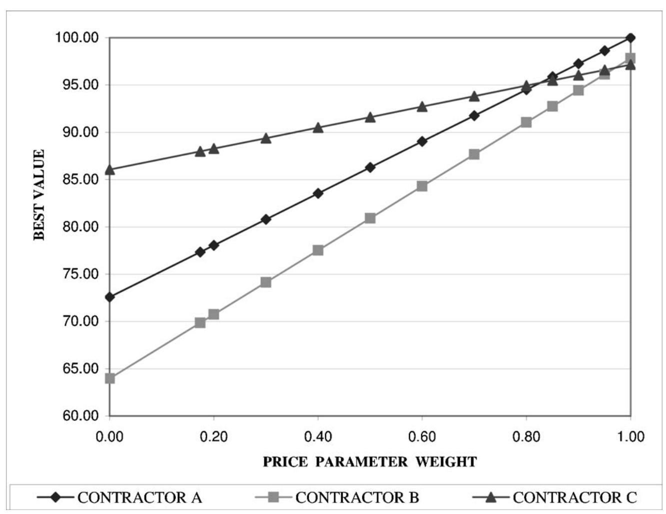

Fig. 4. Sensitivity analysis of change of best-value versus price parameter relative weight for TH-113

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tailored according to specific needs of the project. This flexibility appears in the parameter's selection and weight. The establishment of the best-value model calls the past record of the contractor work for the agency as an indicator of his/her qualification trend. Two different pilot projects are tested during model implementation to clarify the impact of the best-value system on the contractor selection process. Results of model implementation shows the significance turnover from the lowest bid strategy to the choice of the best contractor based on past contractor performance. The maximum score of best-value for both projects has gone to a contractor other than the lowest bidder. This happens as a result of including parameters other than just the lowest bid. Unlike the lowest bid strategy (100% relative weight for bid price), it is noticed that bid price weight ranges between 0.10 and 0.15.

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