MULTI-CRITERIA BID EVALUATION OF PUBLIC PROJECTS

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Abstract
Local and national Governments must deliver the public facilities that citizens need and, at the same time, select private firms that are able to build these facilities according to the best possible compromise between available resources (money, time...) and the quality of the required work/service. Consequently, multi-criteria evaluation schemes, such as the Most Economically Advantageous Tender (MEAT) scheme, are often used by tendering committees in public projects. The used procedure has to meet the requirements of full transparency and to assure competitiveness among bidders. Many MEAT award related models have been proposed in the specialized literature. This paper presents a classification of these models. Their strength and weakness are illustrated. The assessment of some of these models builds upon their application to an example of public procurement. The presented analysis can be used by Governments and public firms in the selection of the tendering mechanism that best meets their requirements, needs and expectations in bid evaluation.

Keywords: public tender, Most Economically Advantageous Tender, supplier selection, bid evaluation

INTRODUCTION

One of the main tasks of local and national Governments is to deliver the public facilities that communities need. This activity involve many challenges, such as gaps in the required financing, need for facilities that meet different qualitative requirements fully, need for their timely delivery, the large number of involved stakeholders and so on.
Consequently Public Procurement has received increasing attention in the specialized literature. This activity has a significant economic relevance. In 2003 the European Public Procurement accounted for more than €1500 billion, equal to about 16% of the EU Gross Domestic Product (Lewis, 2007). In order to implement efficient investment policies, Governments have to encourage competitiveness among candidate suppliers (Malmberg, 2003). In this way, it is possible to build more environmentally friendly public facilities at lower prices and with better quality.

The implementation of efficient Public Procurement procedures is challenged by bid rigging, i.e., the collusion among bidders or between a bidder and a corrupt public officer (Tanaka and Hayashi, 2011). The awarding committee (usually a commission of experts selected by the public authority) must follow prescribed procedures and maintain transparency in public tenders in order to prevent these situations (Panayiotou et al. 2004). Definitively, any given Government aims at obtaining the best possible public goods or services and avoiding collusion: specific laws exist in this regard. In order to meet this goal, a public client must find private firms that can build the required facilities according to the best possible compromise between available resources (money, time...) and the quality of the required work (e.g., in terms of post delivery service, technical features, etc.). Consequently multi-criteria evaluation schemes often are used by tendering committees in this kind of public works.

The European Union Public Procurement Directive 2004/18/EC imposes the use of the Linear Weighting technique (when possible) in the public tenders to be awarded according to the MEAT criterion. This practice is limited by the lack of an optimal choice of weights to be assigned to the evaluation criteria. Moreover, when MEAT is used, public officers can favour a given bidder by assigning a high weight to a criterion that only that competitor is expected to meet fully. Consequently this method is characterized by some subjective choices which make corrupt behaviours possible. In the last few years many models, related to the multi-criteria evaluation of bids, have been proposed in the specialized literature.

Some of these models have been developed for the specific purpose of public construction projects, while others, although aimed at a more general application, can be also applied to evaluating construction bids. Some of these methods address the optimal choice of the weights for the linear weighting. Others are based on the qualitative comparison between alternatives. Another set of methods is based on the estimation of the utility coming from each bid. Lastly, another approach aims at determining the social costs of completion time and the quality of the final work. These costs are added to the submitted bid price.

A classification of several published bidding mechanisms for public projects is proposed in this paper. Their strengths and weaknesses are illustrated. The analysis aims at informing Governments and public agencies the type of mechanism that best meets their requirements, needs and expectations in bid evaluation.

The paper is structured as following. The next section describes the multi-criteria bid evaluation, as proposed by the European directive, and it presents a classification of the considered models, while the following section presents an application of these models to an example of public procurement practice. A final section concludes the paper.

THE MULTICRITERIA SELECTION IN PUBLIC PROCUREMENT

Background

In most countries, public procurement is ruled by specific legislative requirements. In the European Union, this matter is regulated by the 2004/18/EC Directive (European Parliament and Council, 2004), also known as Public Procurement Directive. This law sets the application of one of the two following award criteria: the Lowest Price (LP) or the Most Economically Advantageous Tender (MEAT). The LP criterion is typically used in conjunction with pre-qualification requirements (Lorentziadis, 2010). In this case, money saving is one the main goals of the tender, because the features of the supplied product, service or work are standardized and price is the only element that differentiate offers (Piga and Zanza, 2005). Differently, when the contract is awarded on the basis of the MEAT criterion, various (quantitative and qualitative) factors are considered simultaneously. In this last case, scores for different factors are synthesized into an overall score by using of the linear weighting method (European Parliament and Directive 2004/18). In this regard, the committee has to assign a weight to each criterion before the submission of the offers. These weights are to be specified in the request for proposals (Lorentziadis, 2010). The literature on supplier selection suggests many methods for weights determination (for an overview see De Boer, 1998), but the Public Procurement directive does not impose any specific procedure in this regard. Consequently, weights could be set on the basis of subjective judgments that, of course, create consistency and validity problems in the evaluation process (Lorentziadis, 2010 and Borcherding et al., 1991). In fact, there is no absolutely optimal choice of weights (Dulmin and Mininno, 2007). In addition, when this awarding scheme is used, public officers can give an unfair advantage to a given bidder by assigning a high weight to a criterion that only she can meet fully (Søreide, 2002).

Literature review

In order to overcome these limits, several studies have proposed the adoption of vendor rating methods that are used in the private sector. These instruments can be a valid alternative to the simple linear weighting of performance values that is based on the weights allocated by public officers.

The methods can be classified in five categories:

- *Linear Weighting-based methods*. These use specific algorithms to find weights to be used for scoring each bid
- *Comparison-based methods*. Each bid is compared to all others in a quantitative or qualitative manner. With this procedure, a final score is assigned to each offer through techniques such the Analytic Hierarchy Process (AHP)
- *Cost-Benefit Analysis*. The cost and benefits of each offer are estimated. The weighted sum of these indicators determines the final score.
- *Utility-based methods*. Specific utility curves, as a function of different criteria, are defined to estimate the overall utility of each bid.
- *Costing-based methods*. The cost consequences of non price related performance are determined and summed to the bid cost. The resulting overall cost is the indicator used for award.

Table 1 shows examples of the models that characterize the above illustrated categories.

Table 1:*Methods for multi-criteria bids evaluation.*

Type	**Authors**	**Techniques**
Linear Weighting-based	Lorentziadis (2010)	Linear Programming that defines the weights used for Linear Weighting evaluation
Comparison-based	Costantino et al. (2011)	Fuzzy Analytic Hierarchy Process
	Padhi and Mohapatra (2009a)	Analytic Hierarchy Process + Simple Multi-Attribute Ranking Technique
	Padhi and Mohapatra (2009b)	Fuzzy Analytic Hierarchy Process + Simple Multi-Attribute Ranking Technique
	Sipahi and Esen (2010)	Analytic Hierarchy Process
Cost-Benefit Analysis	Bana e Costa et al. (2007)	Weighted sum of cost and benefit scores determined with the MACBETH method
	Topcu (2004)	AHP-based pre-qualification and weighted normalized sum of pre-qualification score and price

Utility-based	Hatush and Skitmore (1998)	Utility functions for a set of six criteria
	Holt et al. (1993, 1995)	Bidder pre-qualification and weighted sum of utility and cost scores
	Lambropoulos (2007)	Cost-utility and time-utility curves
Costing-based	Ellis and Herbsman (1991)	Sum of bid price and Road User Cost during the construction
	Herbsman and Ellis (1992)	Sum of bid and Road User Cost during the construction with quality cost

Linear Weighting-based methods

Lorentziadis (2010) proposes linear programming for evaluating criteria weights by suggesting the choice of the average of the least or most favourable set of weights for all candidate suppliers. All weights range according to the limits established by the public client. Suppliers can be assigned differing degrees of importance provided that the related criteria are known in advance when the request of proposal is announced.

Even if there is no direct definition of weights by public officers, this model is still subject to discretionary choices about weights range and degrees of importance of candidate suppliers.

Comparison-based methods

Many approaches use performance indices as inputs to the Analytic Hierarchy Process (AHP) for defining the best offer among alternative bids (Sipahi and Esen, 2010). AHP determines a ranking of evaluation criteria through their pair-wise comparison first, and then uses this rating to define the ranking of bids. The pair-wise comparison of all alternatives is performed according to their degree of satisfaction of each criterion. This method sometimes is employed in conjunction with the Simple Multi-Attribute Ranking Technique (SMART) (Padhi and Mohapatra, 2009a). Other techniques use fuzzyfied input data (Padhi and Mohapatra, 2009b). Costantino et al. (2011), for example, determined the best offer in a public tender through a Fuzzy Analytic Hierarchyic Process (FAHP) that was based on pair-wise comparison of alternatives according to different factors and on fuzzyfication according to specific membership functions.

These methods allow the peer evaluation of all bids, however qualitative comparisons could still be made in a discretionary way. At the same time, membership functions in fuzzyfied models cannot be chosen in a univocal way.

Cost-Benefit Analysis

Many authors have argued about the need for differentiating cost and benefit criteria in the evaluation of bids. For instance, Topcu (2004) proposes a model according to which, after the pre-qualification of contractors with weights determined by AHP, each bidder receives a score that results from the weighted sum of the normalized overall pre-qualification score (estimated benefits) and bid price. A similar, but more complex, approach is proposed by Bana e Costa et al. (2007). Cost and benefits are evaluated in different ways. Cost is considered with the use of an adequate coefficient, while benefit is determined by a set of qualitative sub-factors. The shift to a quantitative scale and the definition of a set of weights for the sub-factors is obtained through a pair-wise comparison that is based on the MACBETH method (Bana e Costa and Vansnick., 1994). In this case the trade-off between cost and benefit scores is obtained by a weighted sum (where the weights are selected by decision makers).

These analyses allow the differentiation between the required price and offered benefits of each bid, but do not take into account other non-monetary requirements for completing a project, such as completion time. Moreover, discretionary choices can still affect these models.

Utility based methods
Other authors have focused on evaluating the utility of the overall bids. Holt et al. (1993, 1995), for instance, defined a three-stage evaluation procedure for construction related tenders. After a prequalification phase on the basis of non-subjective criteria, all bids are assigned a score according to the utility resulting from pre-defined project criteria and, successively, a second score is assigned to each offered price. A weighted sum of these two indicators determines the final ranking. Differently, Hatush and Skitmore (1998) use six evaluation criteria (bid value and a set of attributes related to a given bidding company, such as financial strength, technical ability, management capability, health and safety records, and reputation). For each of these attributes, a score is determined. The corresponding utility is given by a curve that is developed after bid opening and reflects all offers. The bidder with the highest overall utility is awarded the contract. A similar method has been proposed by Lambropoulos (2007), with two fundamental differences: the considered criteria are cost and delivery time discounts and the utility curves are defined before the request for proposals and known a priori by all bidders. The main drawback of the utility function is its difficult estimation.

Costing based methods
In the last twenty years, the MEAT award scheme has been also adopted in the United States, namely in the construction sector. Ellis and Herbsman (1991) have proposed bid price and completion time as the basis for awarding highway projects. In the initial formulation of the method, the bid price of each competitor is summed to the cost value of each day of incompletion of the project. For each proposal a factor, known as the Road User Cost per day, is estimated. This includes the client's contract administrative costs and the cost to road users for the unavailability of the road (or lane) during construction. The Road User Cost per day is then multiplied by the completion time (in days) proposed by the bidder and the result is added to the bid price. The contractor with the lowest total bid is awarded the project. The same authors (Herbsman and Ellis, 1992) extended their model by considering also the quality of the work (e.g., in terms of roughness index of provided road asphalt). The analysis of 101 highway projects (that had been awarded with the MEAT method) has showed substantial benefits in terms of time savings in comparison with similar projects awarded with the Lowest Price method (Herbsman, 1995).
The cost estimate of completion time or quality allows the quantification of comparable performance indicators and, at the same time, the use of true values in selecting the best bid. The limit of this method is the difficult estimate of the User Cost.

The literature review shows that the above outlined methods have some limits, notwithstanding their benefits, particularly in the case of highway projects. Most of them are based on some subjective selection criteria, such as the interval between weights or membership functions (to be chosen by public officers). Other methods require the subjective estimation of the bid (i.e., in the pair-wise comparison). The qualitative scores, as defined by a given evaluation committee, can still favour a corrupt bidder (Lengwiler and Wolfstetter, 2006). Consequently, this type of arrangement can undermine the transparency of the process. The distinction between the cost and benefit of each bid, furthermore, does not take into account that any given project requires other resources (e.g., time and maintenance services), in addition to money.

Lastly, some of these methods do not respect the EU legislation, because the awarding conditions are not known before the bid opening (Lambropoulos, 2007).
Consequently there is no absolutely a best method when the bid award according to multiple criteria is considered. A public client should select the method which best fits his expectations and established procurement procedures.

THE APPLICATION OF SELECTED MODELS TO PROCUREMENT PRACTICE

In order to verify how different methods can affect the awarding outcome of a public project, three of the outlined models are applied to a case of procurement practice, namely the renovation of a facility at the Politecnico of Bari, Italy (Costantino et al., 2011). In this public project the target price of the auction $\overline{d}_1$ was € 148500 plus VAT and the maximum project duration $\overline{d}_2$ was 35 weeks. The winning bid was selected according to the MEAT criterion.
The number of bidding suppliers was m=45. Each bid (see Table 2) was evaluated according to n=4 criteria, as specified in the request for proposals. The considered criteria were: 1) Price c_1 (with the corresponding performance value d_{i1} measured in € for the i-th supplier and i=1,…,m); 2) Reduction of project completion time c_2 (with d_{i2} measured in weeks and i=1,…,m); 3) Duration of post delivery free maintenance c_3 (with d_{i3} measured in months and i=1,…,m); 4) Quality of enhancement plans c_4 (with d_{i4} and i=1,…,m to be evaluated according to a 0-10 scale that reflect the quality of changes proposed for the design plans and/or material and component substitution). The criteria used for the award were of quantitative (c_1, c_2, c_3) and qualitative (c_4) nature.
The bids of Table 2, are evaluated according to three different ways: the fuzzy AHP (FAHP) (Costantino et al., 2011), a utility based method and a costing-based method.

Table 2: *Bids, related decision criteria, and ranking*

Vendor	Price	Reduction of execution time	Post-delivery maintenance	Enhancement plans
s_i	d_{i1} **[€]**	d_{i2} **[weeks]**	d_{i3} **[months]**	d_{i4}
s_1	110238.11	8.00	48.00	8.00
s_2	110963.63	4.00	9.00	9.00
s_3	109514.93	20.00	29.00	1.00
s_4	110484.45	8.00	15.00	9.00
s_5	110681.87	13.00	22.00	6.00
s_6	111092.92	4.00	29.00	1.00
s_7	112930.37	15.00	50.00	3.00
s_8	112783.38	7.00	6.00	5.00
s_9	**131714.23**	16.00	108.00	**10.00**
s_{10}	109920.87	17.00	113.00	**10.00**
s_{11}	110821.52	19.00	59.00	2.00
s_{12}	109775.89	11.00	59.00	**10.00**
s_{13}	108511.70	2.00	41.00	**10.00**
s_{14}	111457.61	6.00	108.00	5.00
s_{15}	111127.97	23.00	44.00	8.00
s_{16}	108990.13	4.00	13.00	1.00
s_{17}	115299.67	21.00	94.00	4.00

s_{18}	111242.01	13.00	47.00	9.00
s_{19}	112036.06	**25.00**	29.00	8.00
s_{20}	111461.96	2.00	48.00	**10.00**
s_{21}	111009.58	11.00	12.00	7.00
s_{22}	110504.87	3.00	16.00	**0.00**
s_{23}	110247.06	24.00	113.00	8.00
s_{24}	110438.76	**0.00**	**120.00**	9.00
s_{25}	112457.83	19.00	69.00	7.00
s_{26}	108469.71	20.00	7.00	8.00
s_{27}	110667.84	22.00	28.00	7.00
s_{28}	111660.57	2.00	42.00	4.00
s_{29}	110500.76	10.00	99.00	7.00
s_{30}	110918.29	6.00	**0.00**	2.00
s_{31}	115520.49	20.00	5.00	7.00
s_{32}	119535.68	11.00	20.00	**0.00**
s_{33}	110183.27	23.00	78.00	3.00
s_{34}	109839.68	5.00	88.00	**0.00**
s_{35}	110583.74	7.00	78.00	1.00
s_{36}	110186.17	4.00	54.00	8.00
s_{37}	125075.21	3.00	66.00	7.00
s_{38}	111151.44	22.00	36.00	3.00
s_{39}	109224.97	14.00	89.00	**10.00**
s_{40}	110556.28	14.00	23.00	**0.00**
s_{41}	110575.67	4.00	82.00	4.00
s_{42}	**107967.74**	21.00	22.00	4.00
s_{43}	111367.66	16.00	44.00	8.00
s_{44}	116276.03	9.00	75.00	8.00
s_{45}	118868.15	13.00	94.00	2.00

As far as the FAHP is concerned, the criteria for weights and membership function can be found in Costantino et al. (2011). This method takes into account all the four decision criteria proposed in the tender.

Lambropoulos's model (2007), as an example of the utility-based method, is used in this application. The inputs to this model are the cost and time discounts proposed by each bidder. Because the required duration of the free maintenance period is not specified in the request for proposal, the application cannot consider this performance value. This is also true for the quality of enhancement plans, which cannot be determined on the basis of a purely quantitative scale. Consequently, the offer that maximizes the overall utility function (1) is to be selected

$$U(s_i) = KU(\lambda_{ci}) + XU(\lambda_{ti}) \tag{1}$$

where $U(s_i)$ is the overall utility of the offer of bidder s_i; $U(\lambda_{ci})$ □ [0,1000] is the utility of the price discount by s_i; $U(\lambda_{ti})$ □ [0,1000] is the utility of the time reduction offered by s_i; K and X are the weights of $U(\lambda_{ci})$ and $U(\lambda_{ti})$. The utility functions $U(\lambda_{ci})$ and $U(\lambda_{ti})$ used in this application are expressed by (2) and (3)

$$U(\lambda_{ci}) = \begin{cases} 3000\lambda_{ci} & \text{for } 0 \le \lambda_{ci} \le 0.2 \\ 400 + 1000\lambda_{ci} & \text{for } 0.2 \le \lambda_{ci} \le 0.4 \\ 667 + 333 * \lambda_{ci} & \text{for } 0.4 \le \lambda_{ci} \le 1 \end{cases} \tag{2}$$

$$U(\lambda_{ti}) = \begin{cases} 200\lambda_{ti} & \text{for } 0 \le \lambda_{ti} \le 0.2 \\ -167 + 1333\lambda_{ti} & \text{for } 0.2 \le \lambda_{ti} \le 0.8 \\ 500 + 500 * \lambda_{ti} & \text{for } 0.8 \le \lambda_{ti} \le 1 \end{cases} \tag{3}$$

The parameters λ_{ci} and λ_{ti} are determined according to (4) and (5) respectively.

$$\lambda_{ci} = \frac{\bar{d}_1 - d_{i1}}{\bar{d}_1} \tag{4}$$

$$\lambda_{ci} = d_{i2} \tag{5}$$

The values of the weights used for the two utility functions are respectively K = 0.55 and X = 0.45.

As far as the costing based method is concerned, the following evaluation approach is proposed. The user benefits that result from the time reduction (*tub*) and the free maintenance (*mub*) are subtracted from the bid price. Thus the total bid cost b_i (6) is obtained through

$$b_i = d_{i1} - tub \cdot d_{i2} - mub \cdot d_{i3} \tag{6}$$

In this case, the time reduction benefit has been assumed to be equal to *tub* = 800 €/day, while the free maintenance is equal to *mub* = 50 €/week.

Table 3 shows the scores of all offers according to the three considered methods.

Table 3: *Bid scores according to the three considered methods*

Vendor s_i	**Overall performance**		
	FAHP	**Utility-based**	**Costing-based**
s_1	0.4243	423.85	101438.11
s_2	0	369.31	107313.63
s_3	0	632.25	92064.93
s_4	0	422.94	103334.45
s_5	0	507.92	99181.87
s_6	0	368.83	106442.92
s_7	0.4714	533.88	98430.37
s_8	0	397.28	106883.38
s_9	0	385.79	113514.23
s_{10}	0.8069	579.31	90670.87
s_{11}	0.4472	610.26	92671.52
s_{12}	0.6835	476.99	98025.89
s_{13}	0.2593	373.25	104861.7
s_{14}	0.5657	372.62	101257.61
s_{15}	0.3300	677.70	90527.97

s_{16}	0	376.62	105140.13
s_{17}	0.3973	627.96	93799.67
s_{18}	0.4007	505.85	98492.01
s_{19}	0	**708.62**	90586.06
s_{20}	0.3266	362.32	107461.96
s_{21}	0	472.42	101609.58
s_{22}	0	368.44	107304.87
s_{23}	0.400	698.11	85397.06
s_{24}	0	360.97	104438.76
s_{25}	0.5922	604.20	93807.83
s_{26}	0	636.12	92119.71
s_{27}	0	662.26	91667.84
s_{28}	0.2828	361.59	107960.57
s_{29}	0.7303	457.17	97550.76
s_{30}	0	374.62	106118.29
s_{31}	0	610.00	99270.49
s_{32}	0	435.40	109735.68
s_{33}	0.5477	681.20	87883.27
s_{34}	0	376.04	101439.68
s_{35}	0.3162	405.43	101083.74
s_{36}	0.4619	372.19	104286.17
s_{37}	0.0413	267.99	**119375.21**
s_{38}	0.1414	660.47	91751.44
s_{39}	**0.8641**	530.46	93574.97
s_{40}	0	525.53	98206.28
s_{41}	0.4619	370.75	103275.67
s_{42}	0	655.12	90067.74
s_{43}	0.3300	556.81	96367.66
s_{44}	0.3408	418.63	105326.03
s_{45}	0.2152	477.10	103768.15

The data of Table 3 shows different results depending on the type of awarding method. According to FAHP, the utility-based and costing based method the winning bid would be s_{39}, s_{19} and s_{37} respectively. Table 4 shows that each method determines very different rankings of the offers.

Table 4: *Top 10 bids according to the three considered methods*

Rank #	FAHP	Utility-based	Costing-based
1	s_{39}	s_{19}	s_{37}
2	s_{10}	s_{23}	s_{9}
3	s_{29}	s_{33}	s_{32}
4	s_{12}	s_{15}	s_{28}
5	s_{25}	s_{27}	s_{20}
6	s_{14}	s_{38}	s_{2}
7	s_{33}	s_{42}	s_{22}
8	s_{7}	s_{26}	s_{8}
9	s_{36}	s_{3}	s_{6}
10	s_{41}	s_{17}	s_{30}

Moreover, the variability in the final rankings of bids is not determined by the choice of the awarding method only, but also by the parameters used in the evaluation. The same method can lead to very different results by changing its parameters. Thus there is the possibility that a given competitor is favoured over the others. This problem has been addressed in specialized literature (e.g., Telgen and Schotanus, 2010).

Consequently, the selection of an awarding method by local and national Government or governmental agencies should take into account two factors: the availability of useful information for setting the evaluation parameters and the possibility of corrupt behaviour.

CONCLUSIONS

The delivery of public projects is one of the main tasks of local and national Governments (or governmental agencies). These facilities must meet a set of economic, technical and environmental requirements. In this regard, the Most Economically Advantageous Tender is increasingly used as the award method of public projects. The literature review has shown that many models can be applied to the MEAT tenders. This paper has addressed and discussed some of these models. Five types of awarding mechanisms have been outlined. All of them require the setting of some selection parameters and sometimes they are based on the subjective evaluation of offers.

Three of these methods have been applied to evaluating the bids for the renovation of a facility at the Politecnico of Bari, Italy. The data show different outcomes depending on the considered method. The correct evaluation of bids depends on a method that is characterized by fair air and precise parameters and minimizes the possibility of anticompetitive behaviour.

Future research should address the development of an awarding method that is based on objective evaluation and without the need for selecting parameters for ranking.

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