Schöttle, A., and Arroyo, P. (2016). "The Impact of the Decision-Making Method in the Tendering Procedure to Select the Project Team." In: *Proc. 24rdAnn. Conf. of the Int'l. Group for Lean Construction*, 20-22 July, Boston, MA, USA, sect.3 pp. 23-32, Available at: <www.iglc.net>.

THE IMPACT OF THE DECISION-MAKING METHOD IN THE TENDERING PROCEDURE TO SELECT THE PROJECT TEAM

Annett Schöttle[1], and Paz Arroyo[2]

ABSTRACT

Social interaction between the owner and the team starts with the tendering procedure. Many public owners use only cost to select the project team. Cost is easy to define and measure, but does not necessarily result in the best team. Some public owners use multiple factors (e.g. quality, expertise, technical capabilities) to find the best team based on a Multiple-Criteria Decision-Making (MCDM) method like Weighting Rating Calculating (WRC) or Best Value Selection (BVS). However, both methods have many shortcomings when helping owners in differentiating among proposals, such as mixing value and cost. We argue that there is a better way of evaluating proposals. We state that public owner should use Choosing By Advantage (CBA) to select the project team. The method is not used in the tendering procedures yet, but could be beneficial in helping owners discern relative value between proposals. CBA is a system, which uses well-defined vocabulary to ensure clarity in the decision-making process. Previous studies already illustrate that CBA provides benefits in order to differentiate between alternatives, because decisions are documented in a greater detail, with a higher level of transparency, and value and cost is separated. This paper builds on a previous research and presents sensitivity analysis on the data of a public project in San Francisco.

KEYWORDS

Best Value Selection, Choosing By Advantage, Weighting Rating Calculating, selection, tendering procedure, project team.

---

[1] PhD Candidate. Karlsruhe Institute of Technology (KIT), Institute for Technology and Management in Construction (TMB), annett.schoettle@kit.edu, Advisor: Prof. Dr.-Ing. Fritz Gehbauer, M.S.

[2] Assistant Professor. Pontificia Universidad Católica de Chile, Chile. Phone +56 22354-4244, parroyo@ing.puc.cl.

INTRODUCTION

The method used to differentiate between bidder in a tendering procedure has a big impact on which team is choose to pursue a project, and these of course has an impact on how the project is delivered and its outcomes. The public tendering differs to the private selection process, as different regulations have to be considered and take into account for developing the procedure. A public tendering requires a fair competition which assesses bidders objectively. Therefore, a clear and well developed method is necessary. Factors for assessment as well as the assessment itself need to be defined and explained upfront, before the tendering starts. Once the tendering is carried out, a meaningful change can easily result in claims against the process. Usually Weighting Rating and Calculating (WRC) or Best Value Selection (BVS) are used to select the project team. WRC and BVS are value based Multiple-Criteria Decision-Making (MCDM) methods, which are described in Belton and Stewart (2002). Compared to WRC and BVS, Choosing by Advantages (CBA) is a MCDM-method which weights the importance of the advantages (IoA) based on relevant differences between the alternatives, rather than weighting factors and attributes separately as WRC and BVS does. Using CBA is a paradigm shift (Suhr 1999). Schöttle et al. (2015) did a first analysis of the three MCDM-methods WRC, BVS, and CBA in the tendering procedure to select the project team. This paper compares the three methods using sensitivity analysis in the constructed case.

RESEARCH METHOD

This research builds on a previous research comparing CBA with WRC and BVS in the tendering procedure (Schöttle et al. 2015). The research questions of this paper are:

- How do WRC, BVS, and CBA affect the selection of the project team?
- Which method would be best for selecting the project team?

Based on the constructed case (Schöttle et al. 2015) further simulation will be done using sensitivity analysis (e.g., Triantaphyllou 2000) as well as extreme cases (e.g., Flyvbjerg 2006) to show the impact of the decision-making method and the input variables on the bidder ranking. The analysis contains the impact of the price and score in order to rank the bidders. This paper does not discuss the topic of implementation of CBA in the tendering procedure. The paper first explains and compares the three methods. Secondly, a briefly overview about the development of the constructed case and the results of the previous study is given. Then different sensitivity analyses are presented and the findings are discussed. Finally, the authors conclude and give a statement to further research.

THEORETICAL OVERVIEW

CBA is a MCDM-method which is based on a well-defined vocabulary. Suhr (1999) defines a factor as an element of a decision, a criterion as a "standard on which a judgement is based on", an attribute as a characteristic of an alternative, and an advantage as the "difference between the attributes of two alternatives." CBA compares advantages between alternatives and assigns scores only to alternatives which present an advantage in a factor. Every advantage is linked to the paramount advantage, which reflects the most important advantage for the decision-maker, which in this case is the owner. The principle of anchoring is the key element to assign scores, and cost and value are studied separately. CBA have been successfully used for choosing designs, systems, and materials in the AEC industry to transparently document collaborative decisions (Grant 2008; Nguyen et al. 2009; Kpamma, et al. 2015). It is easy to understand what attributes or characteristics of the alternatives are more valued by the owner. Besides, the method is influenced by IoA and scale of importance, but the anchoring leads to less subjectivity compared to WRC or BVS. In WRC and BVS results are strongly influenced by factor weight, scoring scale, and score of attribute. Weights represent the importance of a factor for the decision-maker and a score of attribute represents the fulfillment of a factor (Triantaphyllou 2000; Belton and Stewart 2002). Every factor of each alternative is scored although the alternative provides no advantage in the factor. WRC and BVS methods do not postulate anchoring factor weights according to the differences between alternatives' attributes. This unanchored judgement leads to unclear meanings of weights and scores resulting easily in misinterpretation. WRC and BVS differ in the strategy of cost consideration. In WRC cost is a factor and the decision is based on the highest score. BVS decisions are based on the lowest cost per score ratio. Even though the ratio represents cost per score, BVS is often defined as a ratio of bid price per value. We state that this definition is incorrect as value is the way of achieving an objective, which can be very different dependent on the individual.

All three methods assign scores individually to factors or advantages in a factor even when factors can be interdependent. For example, an owner could evaluate factors that are related, such as energy efficiency of the building and expected CO_2 emissions during operation. These two factors are related, but an owner may ask to provide information for both, which in a way might be double counting factors, or over valuing the same attribute for a proposal. None of the 3 methods will prevent this to happen. Therefore, owners should carefully consider which factors will be assessed in the decision, and should avoid highly correlated factors. Figure 1 specifies the process steps of all three methods.

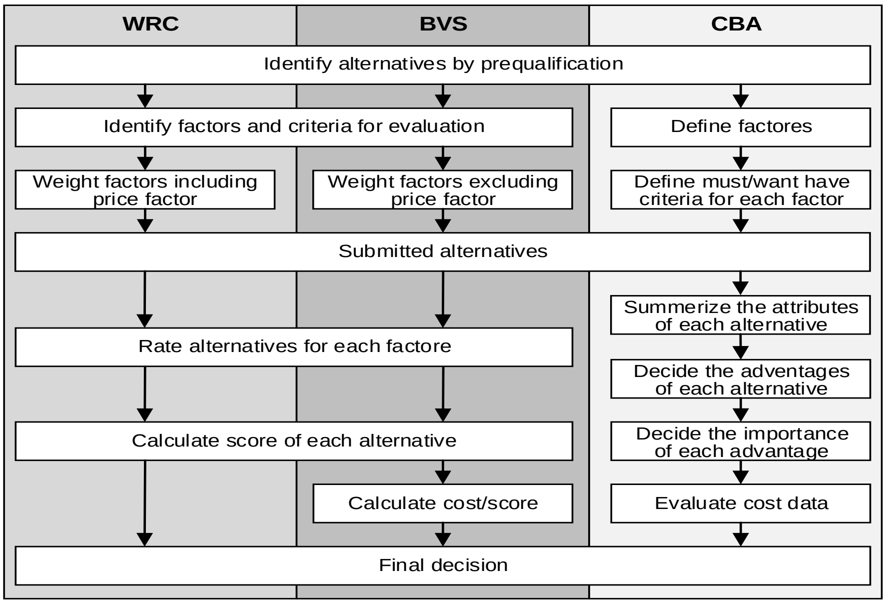

Figure 1: Process steps of WRC, BVS, and CBA

WRC and BVS are easy to implement, because people are used to weight factors and assign scores to attributes. To implement CBA training is necessary. Often the method is implemented wrong. One problem is that some publication applied CBA incorrectly (see Haapasalo et al. 2015 or Rolstadas et al. 2014)[3]. For example, Haapasalo et al. (2015) has many paramount advantages as the authors assigned the highest score (in this case 100) in more than one factor which may lead to confusion, and they state that "factors can be weighted differently based on their importance; however, all the factors are equally weighted in this study", which actually is contrast to the CBA principles where decisions are based on IoA not importance of factors. Furthermore, they scored alternative which provide no advantages. Their example is not transparent as it is not clear how they assigned scores and what the criterions are. Rolstadas et al. (2004) also scores alternatives which provide no IoA. Moreover, both have incorrect sums. The ranking of the alternatives would be different, if CBA would be applied correctly.

CASE BACKGROUND

As stated in the Schöttle et al. (2015) in the tendering procedure an alternative is a proposal, a bidder, or a project team which submitted a proposal. We will use the term bidder synonymously as alternative. The decisions consist in evaluating 3 bidders which are represented as B1, B2, and B3.

The constructed case is based on the tendering procedure of the UCSF academic office building Mission Hall located in San Francisco. To select the project team, every bidder submitted a technical and a price proposal. The technical proposal contains also management skills and knowledge. Both proposals are submitted separately, but to the same deadline. To score objectively, the owner is not allowed to open the price proposal before the technical proposal is scored. The simulation consists of 18 factors clustered in seven categories. The weights (W) of each category are based on the maximal achievable score for each category of the real case. The Development of the scoring scale (0-5) as well as the assignment of the scores is based on the available information where (0) means 'doesn't meet minimum requirement' and (5) means 'exceeds requirements'. As the real case had a stipulated sum, the price proposals were assumed with $ 93.8M for B1, $ 92.5M for B2, and $ 93.7M for B3. In order to compare WRC with BVS, the price factor is weighted 50 % in WRC. Table 1 one shows the scoring of WRC and BVS as well as the scores for IoA in CBA. In CBA the B1 achieved 475 scores, B2 390 scores, and B3 385 scores. The complete CBA table is published in Schöttle et al. (2015).

The bidder ranking of each method is illustrated in figure 2. As shown by Schöttle et al. (2015) for WRC B2 would be selected, who submitted the lowest price proposal and achieved the second best technical score. In the case of BVS and CBA B1 would be selected. B1 achieved the highest score for the technical proposal and submitted the highest price proposal, for BVS that leads to the lowest ration. In CBA the owner (in accordance with law) would also select B1 as B1 achieved significantly the best technical score (B2 achieved 17.89% less then B1 and B3 18.95% less then B1) and compared to B3 the bid price difference is relatively nothing 0.107 % and compared to B2 the bid price difference is relatively very small 1.405 %.

[3] We informed the authors of both publications. Rolstadas et al. (2014) will change it in the next version of the book.

Table 1: Scoring of WRC, BVS, and CBA (Schöttle et al. 2015)

Category Technical Factor	Rating (Scale 0-5)			**WRC Calculating**				**BVS Calculating**				**CBA IoA**		
	B 1	B 2	B 3	W	B 1	B 2	B 3	W	B 1	B 2	B 3	B 1	B 2	B 3
Quality Work & Learning Environment	**3,50**	**3,00**	**2,50**	**0,125**	0,44	0,38	0,31	**0,25**	0,88	0,75	0,63			
1.A Building interior program spaces	4	2	2									100	50	
1.B Workplace	4	3	2									50	30	
1.C Building interior	2	5	3									0	60	40
1.D Daylight	4	2	3									70		30
Model of Architectural & Urban Design	**3,33**	**3,00**	**3,00**	**0,125**	0,42	0,38	0,38	**0,25**	0,83	0,75	0,75			
2.A Sight lines and passageways	3	3	4											60
2.B Façade	3	4	4										80	80
2.C Building interior: Workplace	4	2	1									60	20	
High Performing Building	**3,00**	**3,50**	**4,00**	**0,050**	0,15	0,18	0,20	**0,10**	0,30	0,35	0,40			
3.A Light systems	2	2	5									5		40
3.B Vegetated Roof	4	5	3									10	30	
Environmentally Sustainable	**2,00**	**1,00**	**2,50**	**0,050**	0,10	0,05	0,13	**0,10**	0,20	0,10	0,25			
4.A Water saving	2	2	3											30
4.B Materials	2	0	2									20		20
Durable & long-lasting	**2,00**	**4,00**	**1,50**	**0,050**	0,10	0,20	0,08	**0,10**	0,20	0,40	0,15			
5.A Vibration	2	4	2										40	
5.B Utilities system	2	4	1									10	50	
Efficiently Serviced & Maintained	**3,00**	**3,00**	**3,00**	**0,050**	0,15	0,15	0,15	**0,10**	0,30	0,30	0,30			
6.A Faculty Workspace	4	2	3									90		60
6.B Site lighting elements	2	4	3										30	10
Quality & Clarity of Project Plan	**4,00**	**1,33**	**2,00**	**0,050**	0,20	0,07	0,10	**0,10**	0,40	0,13	0,20			
7.A Last Planner™ method	4	1	2									20		5
7.B Set-based design	4	2	2									20		5
7.C Target Value Design	4	1	2									20		5
Price	**2**	**4**	**3**	**0,500**	1	2	1,5							
Overall score					**2,554**	**3,392**	**2,838**		**3,108**	**2,783**	**2,675**	**475**	**390**	**385**
Price [in million $]									**93,8**	**92,5**	**93,7**			
Cost/Quality point [in million $]									**30,177**	**33,324**	**35,028**			

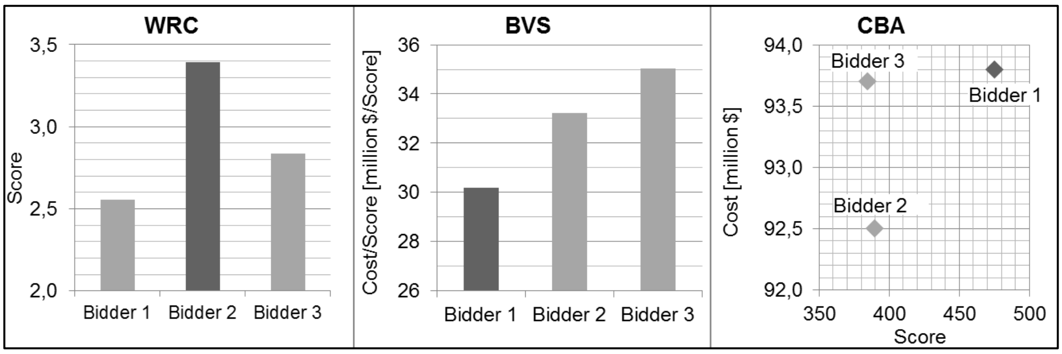

Figure 2: Results (Schöttle et al. 2015)

SENSITIVITY ANALYSIS

The sensitivity analysis was used to show the effects of the methods by changing variables and parameters. The analysis consists of three parts. First the impact of the price factor for WRC was simulated and analyzed. Then the impact of price and overall score for BVS ratio was studied. Moreover, scenarios and extreme cases were constructed to show the impact more clearly. The last simulation shows what happened if equally scored data (category 6) is taken out of the calculation.

IMPACT OF PRICE FOR WRC

By changing the price weight the weight of all other seven categories had to adjust relatively. Figure 3 illustrate the simulation of the price weight for WRC. The lines represent the different bidder submissions as function of the price weight ($y_{B1}(x)$, $y_{B2}(x)$, $y_{B3}(x)$, $y_{B4}(x)$, and $y_{B5}(x)$). It can be seen that as soon as the price factor is weighted 13.98 % B2 will win the bid instead of B1. The weight of the price factor seems small, but has already a high impact on the overall score. With a price weight higher than 30.23 % the proposal with the best performance score will be ranked third place. Table 2 presents the interception of the lines $y_{B1}(x)$ and $y_{B2}(x)$ represented by P_{B1B2} and the interception of the lines $y_{B2}(x)$ and $y_{B3}(x)$ represented by P_{B2B3} as well as the ratio of the performance and price score to the overall score at both interceptions. It is obvious that the closer the technical scores to the price score the greater the weighting has to be to change the ranking and vice versa. Bidder could also submit a proposal which leads to the line $y_{B4}(x)$ or line $y_{B5}(x)$ (see figure 3). B4 shows the extreme case that a bidder could win the bid if the price factor is weighted with 73.57 % when the price proposal achieves the score 5 and the technical proposal achieved 0 scores (see figure 3 P_{B2B4}). Furthermore, the case B5 shows that as soon as the price factor is weighted 50 % a bidder could win the bid with a technical score of 1.783 if the bidder submitted the lowest bid price and achieved 5 scores for the price proposal (see figure 3 P_{B2B5}).

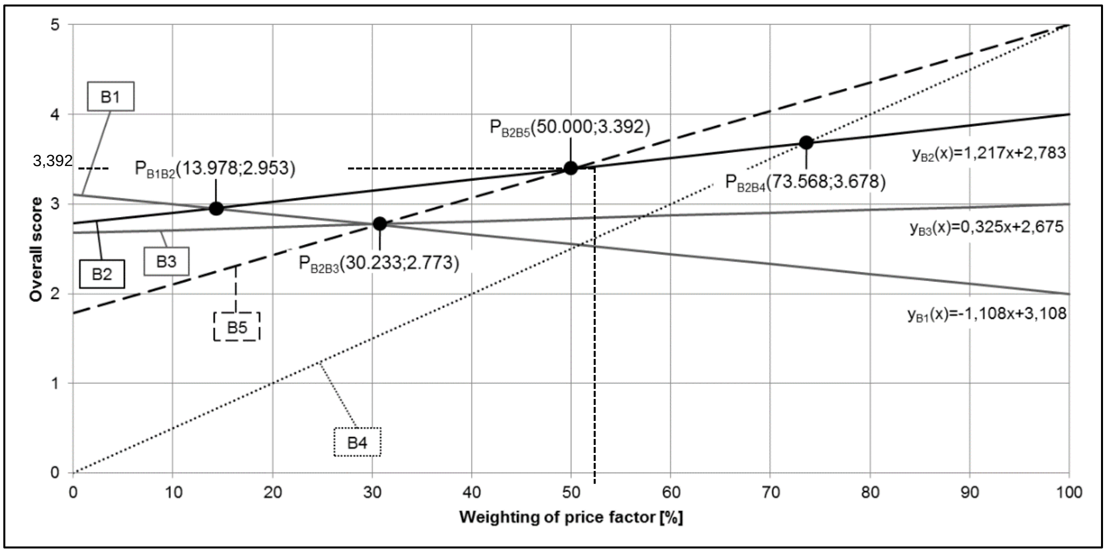

Figure 3: Simulation of the price weight for WRC

Table 2: Interception of the developed lines by simulating the price weight in WRC

	P_{B1B2}			P_{B2B3}		
	B 1	**B 2**	B 3	B 1	**B 2**	**B 3**
Weighted sum of technical score	**2.674**	**2.394**	2.301	2.169	**1.942**	**1.866**
Weighted price score	**0.280**	**0.559**	0.419	0.605	**1.209**	**0.907**
Overall Score	**2.953**	**2.953**	2.720	2.773	**3.151**	**2.773**
Ratio technical score	**0.905**	**0.811**	0.846	0.782	**0.616**	**0.673**
Ratio price score	**0.095**	**0.189**	0.154	0.218	**0.384**	**0.327**

Figure 4 shows what would happen, if the price proposals would be submitted differently and the assigned scores for price change. We show the effects of B1, B2, and B3 scoring 4 ($ 92.5M), 3 ($ 93.7M), and 2 ($ 93.8M). The simulations are represented in the line S4, S3, and S2. Obviously, the lowest bid (score 2) will win as soon as price is weighted 30.23 % (see figure 4). Thus, the price factor impacts the bidder ranking significantly. The higher the price weight the lower the bidders differentiate by the technical factors and the less the ranking differs to lowest bid.

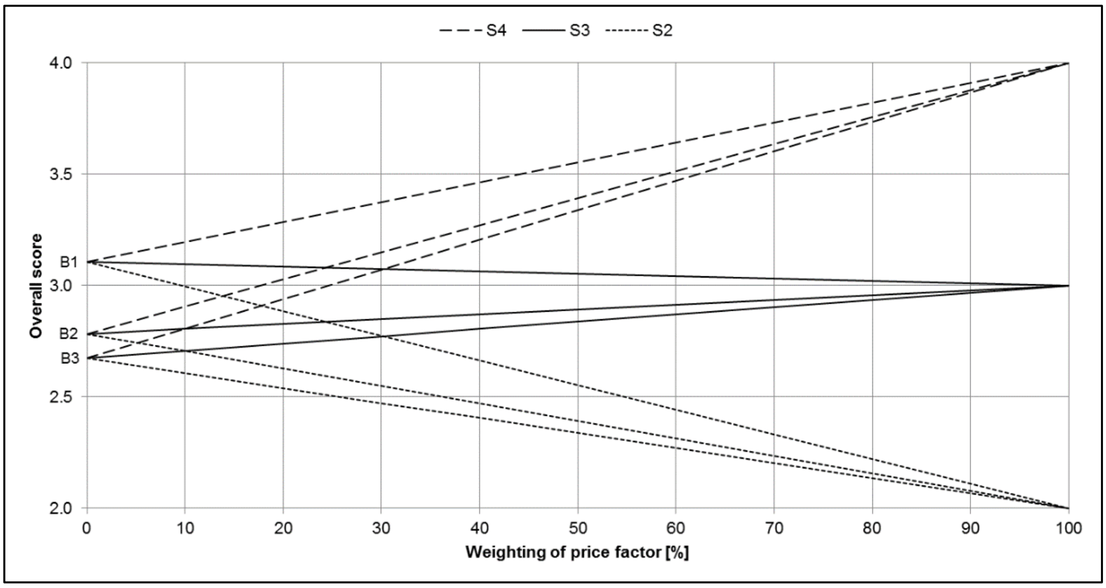

Figure 4: Simulation of scores for price proposal in dependence to the price weight

IMPACT OF PRICE AND OVERALL SCORE FOR BVS

Schöttle et al. (2015) stated that an issue with the BVS ratio could be that "may be an alternative [exists] that has a great cost/score ratio, but the cost may be over budget". The following sensitive analysis will have a look on this subject in detail. Basis of the sensitive analysis is the constructed case with B1, B2, and B3 as shown in figure 5. Now, two scenarios could happen (see figure 5). First, bidder B4 is part of the tendering process and achieved a technical score of 3.2 and submitted a price proposal of $ 96.0M. Compared to all other bidders, B4 submits the highest price proposal, but also achieved the best technical score leading to the best ratio of price per score with 30.000M $\score and therefore wins the bid. Although the price proposal of B4 is $ 2.2M higher than the price proposal of B1 and the technical proposal between B4 and B1 just differ in 0.092 scores the public owner had to select B4. This means that the owner would pay $ 2.2M to get 0.092 more points on the scoring scale. In the second scenario instead of B4 bidder B5 is part of the tendering process and submits a price proposal of $ 90.0M and achieved a technical score of 2.9. In fact, compared to B1 the technical proposal of B5 achieved 0.208 less on the scoring scale, but he difference in the price proposal is $ 5.2M. Even though it could be a better offer for the public owner, B5 will not be selected as the ratio of price per score is higher as the ratio B1 achieved (31.034M $\score > 30.177M $\score). The question here is, is this really value for money? Figure 5 shows clearly the impact of the price proposal for the bidder ranking. As long as another bidder achieves a ratio less than 30.177M $\score B1 would not win the bid. For example, we assume that a bidder achieves the ratio 30.0M $\score and therefore wins the bid. This ratio includes extreme cases. It could happen that a bidder achieves a technical score of 5 and submits a price proposal of \$ 150.0M or a bidder achieved a technical score of 1 and submits a price proposal of \$ 30.0M. The technical scores differ in 4 and the price spread is \$ 120.0M, which amounts a difference of 80 % ($1 \leq x \leq 5$ and \$ 30.0M $\leq x \leq$ \$ 150.0M). In both cases bidders win the bid even though this is anticipated to be less valuable for the owner.

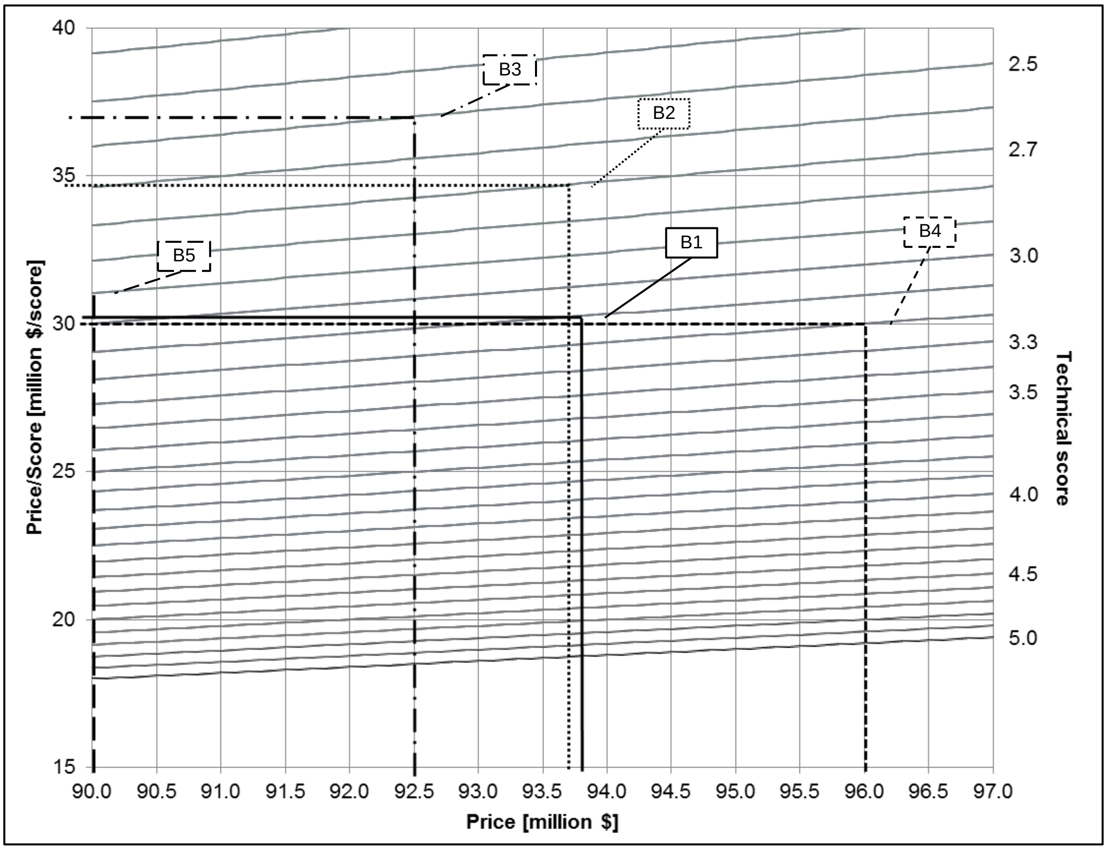

Figure 5: Sensitive analysis for the BVS ratio

IMPACT OF CATEGORY 6 IN WRC AND BVS

For category 6 (C6) "Efficiently Serviced & Maintained" every bidder achieved the same score in WRC and BVS. The following sensitive analysis shows the impact of C6 by changing the weight of C6 and changing all other weights proportionally (excluding the weight of the price factor for WRC). Figure 6 illustrates clearly that in WRC the result will not change if equally scored data is weighted differently as the method is based on linearity. In the case of BVS the simulation shows that the method is inconsistent in the bidder ranking if equally scored data is weighted differently. As highlighted in figure 6 at a point of approximately 88.43 % B2 would win the bid instead of B1 even though only irrelevant data changed. In CBA this situation is different as scores are only assigned to IoA, if no advantage exists in a factor; no score is assigned to any alternative. It can be seen that for C6 every bidder achieved a different score (B1 90, B2 30, B3 70), but as the factors are not weighted, presenting the categories separately does not make sense. Anyways, the alternatives of one factor will never have the same score. Thus, CBA differentiate very clear between alternatives.

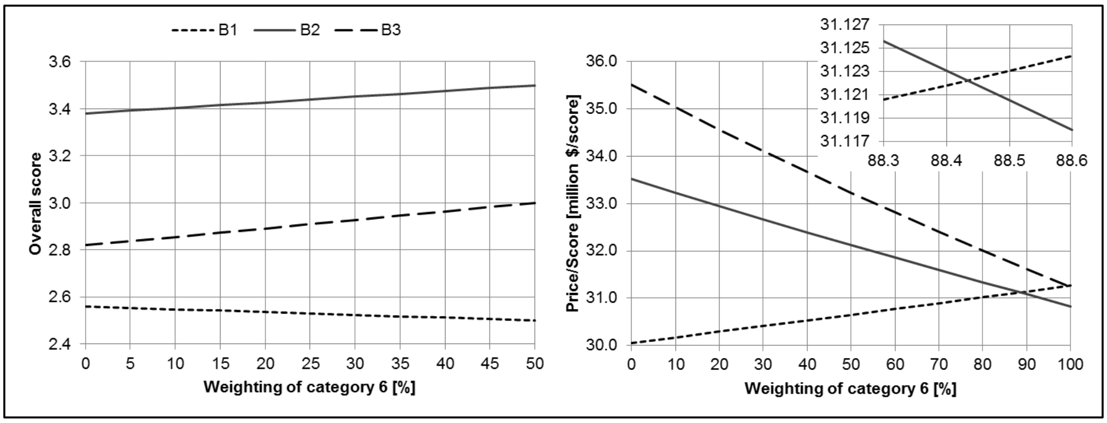

Figure 6: Variation of Category 6

DISCUSSION

The sensitivity analysis of the constructed different cases shows clearly the limitation of the WRC and BVS method. Mixing cost and score can be problematic as it impacts the decision significantly. In WRC a poor technical proposal can still win, if the price proposal is low and the weight of the price factor is with 30.23 % moderately high. It can easily lead to speculative behavior of a bidder trying to win the bid by submitting a low price proposal. As shown in the analysis, in WRC and BVS bidder can still speculate against the tendering procedure in order to win the bid. In both methods the spread between price and technical proposals can be huge, but the overall score in WRC or the BVS ratio can be the same as both methods mix the technical and price score. Hence, cost and score should be studied separately. In the real case the public owner stipulate the bid price, so that the price factor did not impact the bidder ranking. Thus, the owner could define a maximum score which the bidder needs to achieve as well as a maximum accepted price to avoid speculative behavior of bidders. In CBA the problems which are shown in the cases will not happen, as price and technical proposal are studied separately. Even in the case that the price is fixed by the owner; CBA is more beneficial as the way scores are assigned is very transparent and well documented. Scoring 267 factors, like in the real case, with no anchoring makes the scoring irreproducible and not understandable for a third party. Furthermore, decision-making methods should help the decision-maker to ask the right questions in order to make an optimal decision (Arroyo et al. 2014). WRC and BVS do not provide the framework to ask specifically questions compared to CBA tabular method. CBA is based on a specific questions reflected in the criterion to clarify the IoA. In WRC and BVS the meaning of a factor can be very unclear. Bidders can easily misinterpret the meaning of factors and fail in developing a proposal, which offers the best option for the owner.

CONCLUSION

This paper shows the impact of three applied decision-making methods on the bidder ranking and explains why it is beneficial to use CBA in the tendering procedure. CBA is more transparent than WRC and BVS, and does not mix cost with value as WRC or BVS does. However, the implementation of CBA in the public sector still has challenges to overcome. These challenges are related with the widespread practice of publishing factors` weights before receiving the proposals, and therefore owners have to keep them even when factors that are heavily weighted may not differentiate among alternatives. Therefore, further research is necessary to generalize the findings of this analysis and to study how CBA can be implemented in the tendering procedure of the public sector in accordance to the law. Besides, we state that CBA can be improved by overcome the interdependent assignment of scores. Hence, private owners could adopt the method directly.

REFERENCES

Arroyo, P., Ballard, G., and Tommelein, I.D. (2014). "Choosing by Advantages and Rhetoric in Building Design: Relationship and Potential Synergies." *Proc. 22nd Ann. Conf. of the Int'l Group for Lean Construction,* Oslo, Norway.

Belton, V., & Stewart, T.J. (2002). *Multiple Criteria Decision Analysis: An Integrated Approach.* Dordrecht: Kluwer Academic Publishers.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Quality Inquiry,* 12(2), 219-245.

Grant, E. J., and Jones, J. R. (2008). "A Decision-Making Framework for Vegetated Roofing System Selection." *Journal of Green Building,* 3(4), 138-153.

Haapasalo, H., Aapaoja, A., Björkman, S., and Matinheikki, M. (2015). "Applying the Choosing by Advantages method to Select the Optimal Contract Type for Road Maintenance." *Int. J. Procurement Management,* 8(6).

Kpamma, Z., Adinyira, E., Ayarkwa, J., and Adjei-Kumi, T. (2015). "Application of the CBA Decision System to Manage User Preferences in the Design Process." *J. Prof. Issues Eng. Educ. Pract.,* 10.1061/(ASCE)EI.1943-5541.0000258, 05015004.

Nguyen, H. V., Lostuvali, B., & Tommelein, I. D. (2009). "Decision analysis using virtual first-run study of a viscous damping wall system." *Proc. 23nd Ann. Conf. of the Int'l Group for Lean Construction (IGLC).* Taipei, Taiwan.

Rolstadås, A., Pinto, J.K., Falster, P., and Venkataraman, R. (2014). *Decision making in project management.* NTNU Engineering Series, Fagbokforlaget, Norway.

Schöttle, A., Arroyo, P. and Bade, M. (2015). "Comparing Three Methods in the Tendering Procedure to Select the Project Team." *Proc. 23nd Ann. Conf. of the Int'l Group for Lean Construction (IGLC).* Perth, Australia.

Suhr, J. (1999). *The Choosing By Advantages Decisionmaking System*. Quorum, Westport, CT.

Triantaphyllou, E. (2000). *Multi-criteria Decision Making Methods: A Comparative Study.* Dordrecht: Kluwer Academic Publishers.