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To cite this article: Sevilay Demirkesen and Hasan Gokberk Bayhan 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **471** 022020

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Subcontractor Selection with Choosing-By-Advantages (CBA) Method

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Abstract. Construction projects are complex and require the involvement of several parties in order to complete the work with success. Therefore, many construction firms subcontract some of their work packages to successfully execute the projects. To achieve higher rates of performance, contractors need to enhance teamwork and collaboration among project participants. Thinking that complex construction projects require the involvement of multiple subcontractors, it is challenging for main contractors to select best subcontractor for the works requiring special expertise. Especially, projects conducted with Build-Operate-Transfer (BOT) or Engineering-Procurement-Construction (EPC) consists of several parties, where some tasks are challenging and bring the need for collaborative structures. This paper focuses on subcontractor selection, which is a major challenge for many construction firms and uses choosing-by-advantages (CBA) methodology to select the best alternative among different subcontractors. CBA is selected as the research methodology due to its ease of use and priorities over the other multi criteria decision making methodologies such as Analytical Hierarchy Process (AHP) or Weighting Rating and Calculating (WRC). Within this context, the paper first identifies each subcontractor as the alternative and develops factors and attributes for each subcontractor based on various criterion. The paper is expected to guide main contractors to adopt CBA in their subcontractor selection process and assign tasks to the experts of each work package in their projects along with making transparent decisions. The main contractors would best benefit from CBA method to document and track their subcontractors' performance and involve them in the processes at the right time.

1. Introduction

The construction industry has a dynamic nature and is strongly associated with the economic indicators. To successfully manage construction projects, one need to satisfy several criteria such as meeting customer expectations, completing projects under budget and on time. This brings the need for effective decision-making strategies. Strategic collaboration is among those strategies for the successful project management of construction projects since construction activities require different levels of expertise [1], [2].

Aligned with the economic growth, construction projects become larger and complex, which make them hard to manage especially in the decision-making processes of varying tasks. Majority of construction projects involve a high number of project participants such as stakeholders, subcontractors, and owners. Establishing working relations among these parties is very challenging. Therefore, the need for wisely applied strategies becomes a must in almost every project.

Construction projects are executed with the involvement of several parties but subcontractors are of utmost importance in terms of completing different work packages. The need for subcontracting some



of construction works mostly stem from the lack of expertise of main contractors to execute different levels of the construction works. Main contractors prefer to complete project tasks with the help of other parties due to mitigating dispensable costs, escaping from uncertainty and financial burden or carrying out works requiring different specialties ([3], [4], [5], [6]). Hence, it is essential to select subcontractors wisely based on their level of expertise and capacity to carry out the assigned tasks.

This study aims to reveal how subcontractor selection might lead to catastrophic results and what selections strategies are to be applied. Within this context, the study presents three alternatives for subcontractors and adopts Choosing-by-Advantages (CBA) to select the subcontractors based on several criteria. The reason why CBA was adopted as the technique to select subcontractors is that it is a transparent methodology providing a supportive environment. Arroyo (2016) indicates that CBA provides decision makers with differentiating alternatives and selecting the best alternative [7]. This study highlights the importance of selecting subcontractors for the success of construction projects and introduces the application of CBA methodology to subcontractor selection process.

2. Literature Review

The scope of construction projects sometimes requires the assignment of various tasks to subcontractors. Especially, complexity and dynamic nature of construction projects brings the need for subcontractor involvement to effectively execute the projects. In addition, main contractors sometimes are not able to afford cost of having full-time skilled craftsmen in each trade requiring special expertise [8]. Subcontracting on construction projects is a well-established practice ensuring contractors complete their projects on time and under budget in addition to having access to specialized services and risk sharing [9].

However, the effective use of subcontractor skills is strongly related to the project performance. As several researchers point out, 'lowest price wins' mentality often times leads to problems with quality and claims in terms of bringing extra cost [10, 11]. The subcontracting issues also involve problems such as timeliness of payment by main contractor, subcontractor bonding, construction insurance, the process of selecting the subcontractor, and productivity [8]. Among these, it is undeniable that selecting the most appropriate contractors is a challenge for most of the general contractors. The problems with subcontractor selection might stem from the qualitative and subjective nature of selection criteria [12] or the lack of knowledge about the selection criteria [13].

The criticality of selecting subcontractor in construction projects thrilled several researchers to conduct study on either the selection methods or setting selection criteria. For example, Elazouni and Metwally (2000) developed a framework to subcontract best portion of the work based on a decision support system [14]. The system generated financial terms and scheduling plan as the most important criteria to plan subcontractor assignment. Tserng and Lin (2002) indicated that subcontracting a supply chain in the construction might be considered as a global procurement system and an optimized scheme of subcontractors might be reached with this system [15]. Arslan et al. (2008) created a web-based evaluation system for subcontractors called as WEBSES, where subcontractors are evaluated by multiple criterion [16].

Mbachu (2008) further analysed general contractors and subcontractors in South Africa and revealed that the most important criterion for subcontractor selection are the prequalification of subcontractors and tender price [6]. Similarly, Hartmann et al. (2009) conducted research on selection criterion for subcontractors and investigated importance of four factors, namely the price, technical know-how, quality, and cooperation in the selection process [17]. The research revealed that price was the most important attribute in the selection process and indicated that general contractors are not willing to have a price cut. Yin et al. (2009) used data envelopment analysis to evaluate subcontractors in the selection process based on indices of subcontractors [18]. The framework that they developed involved two steps as primary selection and excellent subcontractor selection. They concluded that subcontractors passing these two phases are able to be qualified for contracting [1].

Moreover, general contractors are often times responsible for subcontractor's work to the owner. Failing to meet project success in terms of time, cost, and quality therefore affects general contractors' performance on the project and makes general contractors liable for the failure [19]. Therefore, general contractors' success on the project is strongly associated with the subcontractor performance on assigned tasks [20]. Hence, selecting the right subcontractor for tasks requiring special expertise is essential to have successful project delivery, enhanced performance and reputation as well as survival of the general contractors [6, 16, 17, 21, 22].

3. Choosing-by-Advantages

Decision-making is a multi-dimensional process and the participation of several parties with different viewpoints is often times required in the decision making. Hence, a multi-criteria decision analysis (MDCA) is required to meet the expectations of involved parties [23]. Seppälä et al. 2001 discuss that MCDA is the divisions of a decision problem into its elements, where each element is evaluated separately and then integrated to the system for providing overall insights [24]. CBA is a method developed by Jim Suhr in 1999 [25]. The method consists of a well-defined vocabulary along with an established framework. Decisions are made with evaluating the alternatives in the CBA method. The decision is made having the paramount advantage representing the most important advantage. The method uses anchored judgement, where every advantage of each alternative is compared between an attribute and the least preferred attribute while also comparing every advantage with the paramount advantage [26]. The most important function of CBA in the architecture-engineering-construction (AEC) industry is that it creates an environment, where participatory, transparent and auditable decision processes are applied [27, 28]. Several researchers conducted studies on the application of CBA in the AEC industry listing its advantages over the other decision-making approaches such as analytical hierarchy process (AHP) [23, 27, 28, 29, 30]. Arroyo et al. (2015) highlights that CBA has a more context-based analysis than AHP and does not include conflicting judgements when weighting the factors, where AHP does. In addition, CBA does not consider cost as a factor it rather evaluates it as a constraint, while WRC takes cost as a factor into account but mixes value and cost [28]. CBA provides an overview of the most advantageous alternative but it lacks coming with a final ranking in terms of cost comparison. It rather provides an achieved score to cost that a decision maker can use in making the ultimate decision [26].

CBA continues its rise in gaining popularity among the other lean construction tools [29, 31]. CBA is applied in seven main steps, namely the generating alternatives, identifying factors, defining criteria, describing attributes, establishing advantages, assigning importance to advantages, and evaluating cost data if applicable [25, 27, 32]. The seven steps of CBA along with the tabular method items matched with the steps are shown in Figure 1.

4. Step-by-Step CBA Application for Subcontractor Selection

Step 1: In this study, three alternatives for the subcontractors are provided. Each subcontractor is specialized in soil works and conduct similar types of projects. These three subcontractors provided their offers for a subway construction project.

Step 2: A total of twelve factors were identified, where four of them addressing to 'technical capacity'. The definitions of each factor is given below.

- **Technical Capacity - Number of employees:** Subcontractors address works requiring special expertise and some works need high number of workers so that projects are completed on time and under budget. Availability of high number of employees provide subcontractors with time savings and high quality of work.
- **Technical Capacity - Annual Turnover:** Annual turnover is the indicator of how large is a firm. It also provides general contractor information about how well a subcontractor is financially doing and increases reliability.
- **Technical Capacity - Heavy Machinery Capacity:** The subcontractors of this study are operating in the subway construction and subway construction require the use of a wide

spectrum of heavy machinery and equipment. The technical capacity addressing to owning heavy machines and equipment are of paramount importance for the successful completion of the project.

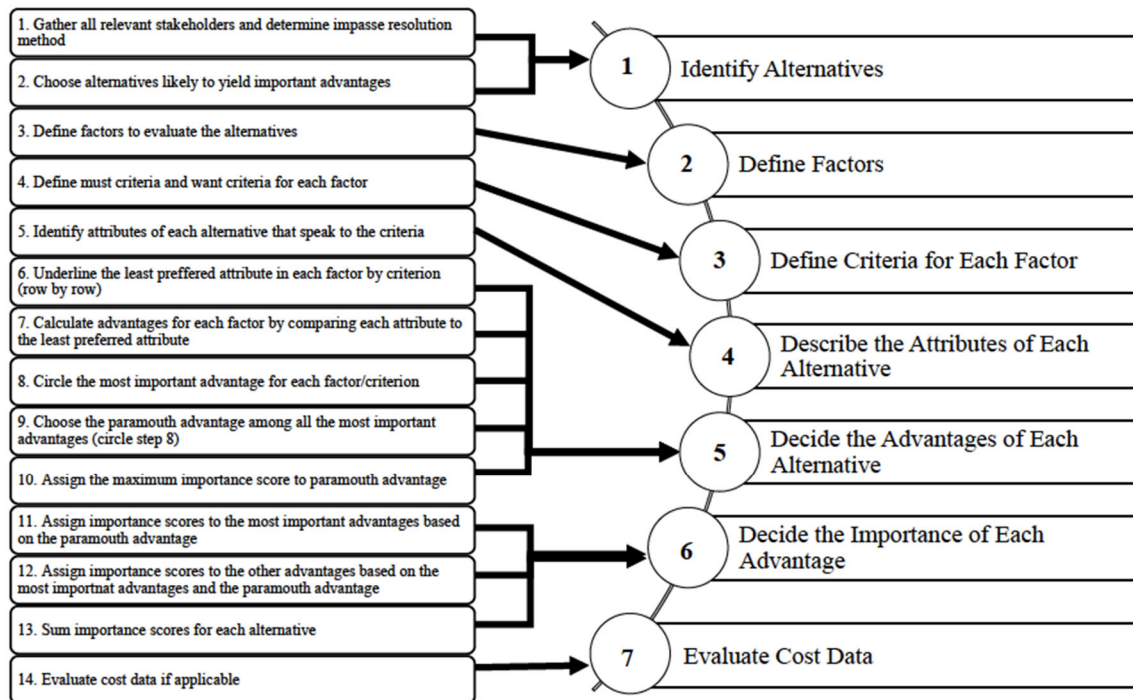


Figure 1. CBA Steps with Tabular Method Items (Adopted from [28], [33])

- **Technical Capacity - Expertise in Different Fields:** Expertise of subcontractors in different fields reflect subcontractor's ability to perform different tasks and evaluation of performance in other fields might give an idea to general contractor about subcontractors' promising skills and capabilities.
- **Level of Expertise in Similar Works - Number of projects completed in similar works:** Level of expertise in similar works is important for general contractor to assess subcontractor's capacity in the subway project. Number of projects completed in similar works is therefore provide a scheme how the subcontractors built upon their skills and capabilities.
- **Safety - Number of accidents including near misses and exempt from work:** Safety is a major concern for several firms operating in the construction industry. The low number of accidents or cases reported indicate how a subcontractor is dealing with safety. High safety performance leads to enhanced performance and quality.
- **Quality-Number of quality certifications (i.e. ISO 9001, ISO 14001, OHSAS 18001):** Each subcontractor is assessed with the quality since quality is one of the core components of successful projects. Based on the fact that subcontractors are ensured about quality with some sort of certifications such as ISO 9001, ISO 14001, OHSAS 18001 and quality is enhanced through these certificates, it is essential that subcontractors possess certain quality certifications.
- **Reputation of Subcontractor - Ranking by Experts:** Each subcontractor is assessed by a subjective ranking by a group of experts depending on their completed projects. This helps general contractor become aware which subcontractor has higher reputation.
- **Risk-Number of risk management certifications (i.e. ISO31000):** Risk attitude of subcontractors is assessed based on the risk certifications that they have. Risk management certifications are to ensure that subcontractors are conducting risk management activities with

success, which is to be handled for the successful operations and improved processes in the projects.

- **Time - Number of Projects Completed on Time:** General contractors are very sensitive about time and budget concerns. Hence, subcontractors are assessed based on their time management skills. The number of projects completed on time is adopted as a criterion to evaluate subcontractors' time management performance.
- **Innovation - Number of patents or innovative designs:** Availability of patents of custom designs reflect subcontractor's originality of work and prove their competences. Therefore, number of patents or innovative designs are adopted as the performance criteria to evaluate subcontractors in terms of strengths in innovation.
- **Current Workload - Total volume of work and number of current projects:** Total volume of work and number of current projects indicate current operability of each subcontractor and prove their capacity to undertake projects in addition to their attractiveness in the industry.

Step 3: In this step, must/want criteria are defined for the factors. For example, for the factor of 'technical capacity-number of employees', a want criterion can be defined as 'the more number of employees are available, the better technical capacity to perform the work'.

Step 4: In this step, attributes are defined for the alternatives. Each alternative has an attribute corresponding to its factor. For example, an attribute for the technical capacity-annual turnover is identified as '30 million USD'.

Step 5: In this step, advantages are decided for each alternative. For example, 'Higher annual turnover and higher reliability for the General Contractor' are identified for alternative 1 considering the attributes of the alternatives with respect to least preferred attribute.

Step 6: In this step, the Importance of Advantages (IofAs) are decided. The sum of IofAs for all factors represent the total importance of the corresponding alternative.

Step 7: Cost data is assessed with respect to IofAs. According to Figure 1, it is seen that Subcontractor 1 has a total cost of advantages of 77,25 million USD where the IofAs score is 560. Subcontractor 2 has a total cost of advantages of 73,75 million USD, where the IofAs score is 125. Finally, Subcontractor 3 has a total cost of advantages of 77,75, where the total IofAs score is 425.

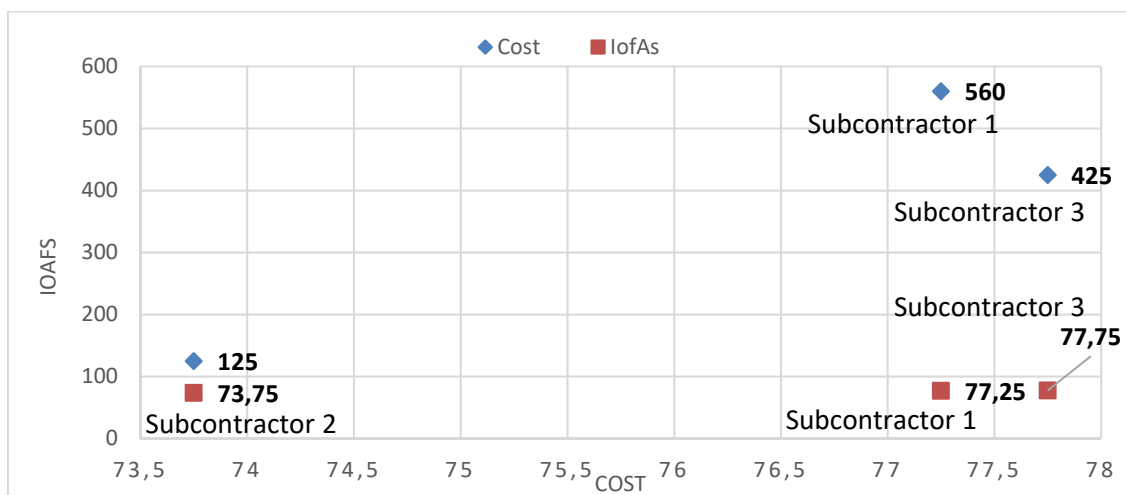


Figure 2. Cost vs. IofAs

Table 1 presents the three alternatives for the subcontractors. It also lists factors, criterion, attributes, and advantages with respect to least preferred attribute. Given with the assigned IofAs, the table shows the total IofAs.

Table 1. CBA Evaluation Table

No	Factor (Criterion)	Alternative 1 - Subcontractor A			Alternative 2 – Subcontractor B			Alternative 3 – Subcontractor C		
		Attrib.	Advantages	IofAs	Attrib.	Advantages	IofAs	Attrib.	Advantages	IofAs
1A	Technical Capacity -Number of employees (higher is better)	800	Higher number of skilled workers and craftsmen on site	50	<u>250</u>	Lower number of skilled workers and craftsmen	15	350	Moderately higher number of skilled workers and craftsmen on site	25
1B	Technical Capacity -Annual Turnover (higher is better)	30 million USD	Higher annual turnover Higher reliability for the General Contractor	80	<u>4.68 million USD</u>	Lower annual turnover Lower reliability for the General Contractor	15	25 million USD	Higher annual turnover Moderately Higher reliability for the General Contractor	70
1C	Technical Capacity -Heavy Machinery Capacity (higher is better)	25 million USD	Higher number of machines and equipment available on site More improved processes and higher quality work	100	<u>1.88 million USD</u>	Lower number of machines and equipment availability Less improved processes and lower quality of work	5	5 million USD	Relatively higher number of machines and equipment availability than Alternative 2 Less improved processes and lower quality of work than Alternative 1	20
1D	Technical Capacity-Expertise in Different Fields (higher is better)	6	Higher Capacity to operate in different areas of expertise Higher ability to perform in multiple sections of the work	30	<u>2</u>	Lower capacity to operate in different areas of expertise Lower ability to perform in multiple sections of work	10	7	Much Higher Capacity to operate in different areas of expertise Higher ability to perform in multiple sections of the work	40
2	Level of Expertise in Similar Works-Number of projects completed in similar works (higher is better)	35	Higher experience in similar works Better performance and higher success	40	<u>11</u>	Lower experience in similar works Less successful operations	10	100	Much higher experience in similar works Much better performance and success	80
3	Safety-Number of accidents including near misses and exempt from work (Less is better)	6	Lower number of accidents, very little cases of exempt from work and almost no near misses	90	<u>36</u>	Higher number of workplace accidents leading to several days of exempt from work and major cases recorded	15	32	Higher number of workplace accidents leading to several days of exempt from work but no major cases recorded	20
4	Quality-Number of quality certifications (i.e.ISO 9001, ISO 14001, OHSAS 18001) (higher is better)	3	Reasonably higher number of certifications ensuring quality of work operations	50	None	No certification recoded	-	3	Reasonably higher number of certifications ensuring quality of work operations	50
5	Reputation of Subcontractor-Ranking by Experts (Upper is better)	1	Higher ranking	30	<u>3</u>	Lower ranking	10	2	Moderately higher ranking	20
6	Risk-Number of risk management certifications (i.e. ISO31000) (higher is better)	<u>None</u>	Risk management certifications are not available	-	1	Slightly higher number of certifications	20	<u>None</u>	Risk management certifications are not available	-
7	Time-Number of Projects Completed on Time (higher is better)	12	Higher number of projects completed on time. Relatively more influential and promising for future projects	30	<u>6</u>	Lower number of projects completed on time Less favourable reputation	15	18	Much Higher number of projects completed on time More influential and promising for future projects	50

No	Factor (Criterion)	Alternative 1 - Subcontractor A			Alternative 2 – Subcontractor B			Alternative 3 – Subcontractor C		
		Attrib.	Advantages	IofAs	Attrib.	Advantages	IofAs	Attrib.	Advantages	IofAs
8	Innovation- Number of patents or innovative designs (Higher is better)	High	Higher number of patents and custom designs available	30	None	No patent or custom design is available	-	Few	Fewer innovative designs are available and patent applications are submitted but no current patent available	10
9	Current Workload -Total volume of work and number of current projects (Higher is better)	125 million USD	Higher volume of work More work reliability	30	<u>30 million USD</u>	Lower volume of work Less work reliability	10	150 million USD	Much Higher volume of work More work reliability	40
	Total Importance of Advantages (IofAs)			560			125			425

5. Conclusions

Selecting best subcontractor is challenging for most of the construction contractors. Therefore, subcontractor selection is a problem for which decision making strategies are needed. This study brings a new approach to subcontractor selection problems and aims at selecting the best alternative among a set of given subcontractor options with the CBA method. Within this perspective, the study identified three alternatives of subcontractor doing similar type of works and specialized in tunnelling works. Their advantages are listed based on several defined factors and attributes. After evaluating three alternatives, it was shown that Alternative 1 was the best choice for the General contractor with respect to highest importance of advantages and lower cost of advantages. The study is expected to guide construction professionals to benefit from the findings of this study and apply CBA in their subcontractor selection process.

Acknowledgment(s)

The authors would like to thank Tuba Baysal Yeşildağ for providing data along with her valuable comments and insights for this study.

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