

Authors. (2017). "Choosing by advantages; benefits analysis and implementation in a case study, Colombia." In: *Proc. 26<sup>th</sup> Annual Conference of the International. Group for Lean Construction (IGLC)*, González, V.A. (ed.), Chennai, India, pp. 636–646. DOI: doi.org/10.24928/2018/0531. Available at: www.iglc.net.

# **CHOOSING BY ADVANTAGES; BENEFITS ANALYSIS AND IMPLEMENTATION IN A CASE STUDY, COLOMBIA**

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## **ABSTRACT**

There are many methods of multicriteria decision analysis (MCDA), each one with properties and benefits. In the Architecture, Engineering, and Construction (AEC) sector most of the time, the decision-making involve different interest of the stakeholders of the projects, must of the times applying methods with the focus on the result. This paper presents a case study of a new University's facility construction that compares the traditional decision-making approach used in the design-bid-build procurement method of AEC industry in Colombia with an MCDA approach. Choosing By Advantages (CBA) has been used to analyse the reasons that could help explain why the subcontractor of a project construction was not meeting the client's expectations during project execution. Results include a discussion of main differences between these decision methods, the main difference is that in traditional decision-making approach the main criterion was cost while in the CBA was value. Consequently, the method's results were different for the alternatives.

## **KEYWORDS**

Choosing By Advantages (CBA), multicriteria decision analysis, contractor selection.

## **INTRODUCTION**

Decision-making may be one of the most common processes that faces professionals in the day-to-day work, but this practice could be very complex, especially when several objectives, factors, criteria and alternatives must be considered. Nowadays there are

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many decision-making methods aimed to obtain the best results for the decision-making process, but its application used to be complex with questionable or mixed results at best.

In the Architecture, Engineering, and Construction (AEC) sector, the decisions taken are of great importance in order to increase the value in the different stages of the projects. One of the most critical decisions is the selection of the contractors, which implies not only the cost of the different alternatives but also technical and quality factors among others. Due to the importance of this process, this research analyses and compare the traditional methods used actually in the Colombian Industry with the Choosing By Advantages (CBA) method in the selection process of the structural contractor in a new University's facility construction.

In order to expose this proposal properly, this research is organized as follows. First, a literature review of the state-of-knowledge of the decision-making in the AEC is shown and consequently the next section details the traditional method selection used in the design-bid-build procurement method in Colombia. Next, a real academic construction project is used as an example of application, exposing and comparing the results obtained by the traditional and CBA method. Finally, on the basis of the results obtained, the conclusions, limitations and further research are drawn.

## **STATE OF THE ART**

The multidisciplinary nature of decision-making in the AEC sector and the involvement of multiple stakeholders, such as designers and users, often result in decision tasks with multiple objectives (Kpamma, Adinyira, Ayarkwa, & Adjei-Kumi, 2016). An example of this is the construction project outcome that may be measured in terms of time, cost and quality achieved (Holt, Olomolaiye, & Harris, 1995). Commonly, the time-cost trade-off problem is a known as bi-objective problem in the field of project management where quality has been considered as an objective which is improved by increasing the cost of the project (Fallah-Mehdipour, Bozorg Haddad, Rezapour Tabari, & Mariño, 2012).

In the example above, there is a conflict management situation where the decision involves multiple objectives. How is shown in the Figure 1, the nature of these decision tasks calls for approaches known as multicriteria decision-analysis (MCDA) (Abraham, Lepech, & Haymaker, 2013). The MCDA may be considered as a complex and dynamic process (Kumar et al., 2017) including two levels: one managerial and one engineering level. The managerial level defines the objectives and chooses the best alternative and in the other hand, the engineering level defines the different alternatives and points out the consequences of choosing any one of them from the standpoint of various criteria, in this order of ideas; this level also performs the multicriteria ranking of alternatives (Opricovic & Tzeng, 2004).

Furthermore, there are many methods of MCDA, its use depends on the functions defined in the problem (Kumar et al., 2017). The CBA decision system developed by Jim Suhr (1999) is one of the methods that takes into account the comparisons of the advantages of alternatives (Kpamma et al., 2016) in order to construct the preferences of the decision-makers (Arroyo, Tommelein, & Ballard, 2012). Consequently, CBA

promotes the correct use of information (Karakhan, Gambatese, & Rajendran, 2016) basing decisions in objective questions, relevant facts, more consistent and less subjective processes (Suhr, 1999).

In the literature review, CBA is not well known (Schöttle & Arroyo, 2017) but increasingly it has become a valuable method because consider different factors, which affect the alternatives as social and environmental factors that are not traditionally considered (Arroyo, Tommelein, & Ballard, 2016). In contrast with other methods, CBA considers cost separately from other factors and does not treat it as a criterion (Parrish & Tommelein, 2009), in other words, in CBA, the cost is considered as a restriction and not as a factor.

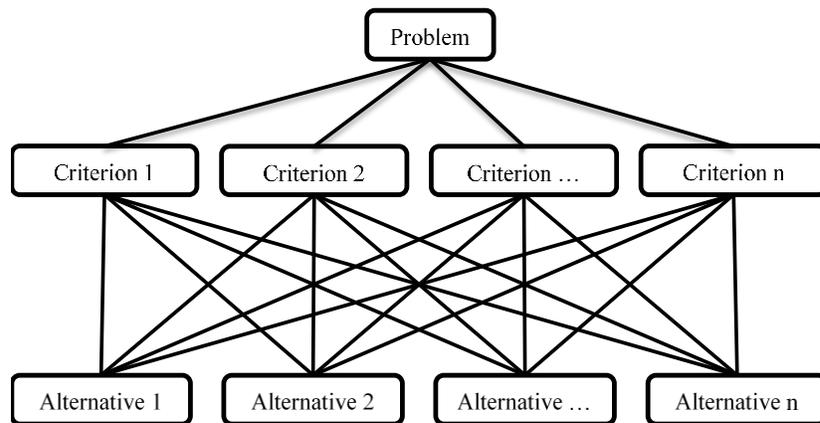


Figure 1: Multicriteria decision analysis diagram (Vallejo-Borda, Gutierrez-Bucheli, Pellicer, & Ponz-Tienda, 2015)

The general phases of CBA implementation have evolved thanks to innovation phases. Paz Arroyo et al. (2013) describe that CBA Tabular method, for moderately complex decision, consist of seven steps: (1) identify alternatives, (2) define factor, (3) define must/want have criteria for each factor, (4) summarize the attributes of each alternative, (5) decide the advantages, (6) decide the importance of each advantage and (7) evaluate money data. In addition, the terminology used by CBA for the decision-making process must be understood before making any application (Martinez, Tommelein, & Alvear, 2016):

- **Alternative:** Person, thing or plan which is a subject of choice.
- **Factor:** An element, part, or component of a decision.
- **Criterion:** A decision rule, or a guidance – usually, either a must or want.
- **Attribute:** A characteristic, quality, or consequence of one alternative.
- **Advantage:** A benefit, gain, improvement, or betterment.

The use of CBA in the AEC industry has been framed, in its majority, in the design and construction decision making (Parrish & Tommelein, 2009) for example to select the formwork system (Martinez et al., 2016), the ceiling tile (Arroyo et al., 2013), the fall protection measures (Karakhan et al., 2016), the sustainable materials (Arroyo et al.,

2016), among others. In the case of contractor selection, the MCDA is suggested to be a viable method (Cheng & Li, 2004) and especially for contractor selection, it has been used methods like weighting-rating-calculating (WRC), best value selection (BVS), and CBA (Schöttle & Arroyo, 2017). Despite that, in Colombia Lean Construction has being explain in three main pillars: culture, philosophy and technology with various methodologies (Pellicer & Ponz-Tienda, 2014), even so, the use of new tools is difficult and face similar barriers related to contractors' engagement, reluctance to change and lack of training (Mejía-Plata et al., 2016). However, the research is limited about the differences based on a comparison of CBA and traditional industry methods of contractor selection, which have a similar nature to the value-based decision-making methods (usually confused with cost) that is based on the factors to be evaluated.

## **TRADITIONAL METHOD OF CONTRACTOR SELECTION**

The contractor selection processes in the construction industry could be the most complex procedures in terms of the data analysis, due to the amount and nature of the data required for the decision problem. In order to provide transparency to these processes, guidelines and general rules were established to carry out the selection and hiring processes in Colombia through the law 80 of 1993. This document, updated with the law 1150 of 2007, institute the principles to ensure the objectivity in the selection. In this sense, the choice is made to the offer more favorable and following the purposes of the contractor, without taking into consideration the factors of any kind of subjective motivation like affection or interest.

It also establishes that the selection and qualification factors, which are established in the contract specifications, have to include criteria such as legal capacity, experience conditions, financial and organizational capacity of the proponents. In the same way, the requirement of such factors must be adequate and proportional to the nature of the contract to be subscribed and its value. Finally, it is established that the most favourable offer will be the most advantageous for the contractor, taking into account the technical and economic factors contained in the specifications.

In the case of entities of a private nature, the law 80 does not act as a binding regulation, but as a guide or principles with the aim of generating transparency in the decision processes. This is reflected in the fact that, despite not being obliged to do so, most private organizations structure their search and selection processes for contractors as established in Law 80. In these processes, the documentation that allows to evaluate the factors that are requested and described in the legislation, in addition to the methods of weighting or scoring of the proposals, both in technical and economic aspects, which, by assigning a percentage to the factors, are adapted to take into account value the compliance for each proponent.

## **RESEARCH METHOD**

The focus of this study is the comparison of the CBA with the traditional method in the Colombian AEC Industry. With the goal of establishing if the CBA method provides

significant advantages and add value over the other method, first, a background literature study of MCDA was made in order to deepen about the CBA application and its relation with similar methods used for contractor selection. In addition, from the case study, it was possible to compare the results of CBA using the process proposed by Paz Arroyo et al. (2013) with the results obtained based on the selection and hiring processes through the law 80 of 1993 of Colombia. Finally, the paper analyses the impacts of the decision taken on the project develop.

## **CASE STUDY**

The selected project is an University's facility construction conformed by 8,555m<sup>2</sup> constructed in irregular five stories and three basement building located in the middle of the campus of the Universidad de Los Andes (see Figure 2), located along the slope of the eastern range of the Andes Mountains.

The main procurement method adopted at Universidad de Los Andes is Design-Bid-Build (DBB). Moreover, this building was not the exception. When the project is in the construction-building process, most construction systems are already assigned to a contractor and a few ones are now in the final phase of the bidding process. In order to support these decisions, the project manager provided all the project information needed for the process: a) the contract specifications where specify the factors and the criterions, b) the four alternatives proposals and c) the tendering evaluation used to take the decision.

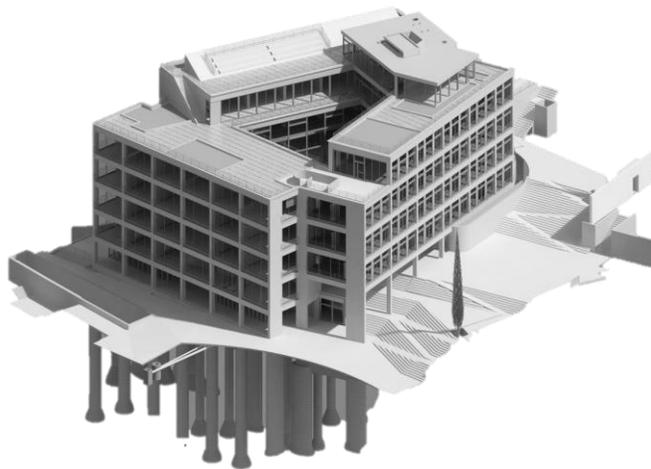


Figure 2: Revit model of Case Study

## **TRADITIONAL METHOD RESULTS**

The structural contractor on a project was selected by a traditional method, according to the law 80 of 1993, as is shown in Figure 3 taking into account the technical and economic criteria contained in the specifications.

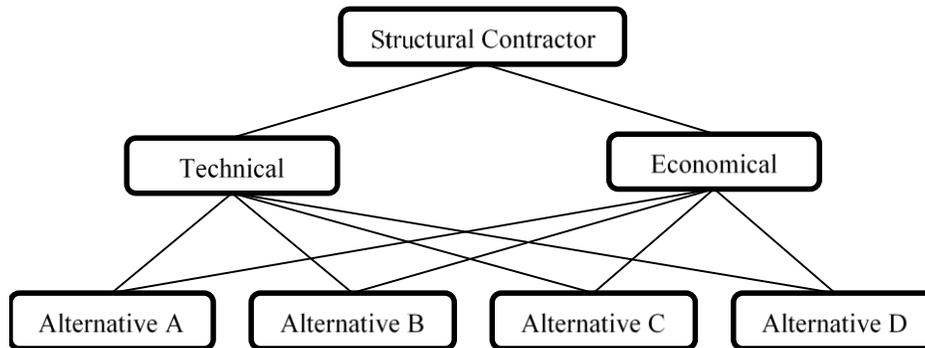


Figure 3: Multicriteria decision-analysis diagram

The economic evaluation has 700 points and the technical only 300 points. The cost as a factor has 550 of 1000 possible points (view Table 1), which tilt the balance in the cheapest alternative.

As can be seen in Table 1, the tendering D was the most favourable bid, and consequently, it was selected to build the structure phase of the project. Note that in the technical evaluation, it was “the worst” but due to the economic ponderation evaluation it was selected as the “the best”, with a final difference of only one point.

Table 1: Results obtained by the traditional method

			Tendering			
Evaluation criteria		Points	A	B	C	D
Technical evaluation	Business organization	150	140	123	121	88
	Management system	50	0	50	50	0
	Planning and logistic	50	50	48	50	38
	Makespan	50	38	42	50	42
	<b>Sub Total</b>	<b>Max 300</b>	<b>240</b>	<b>272</b>	<b>255</b>	<b>209</b>
Economic evaluation	Equity	26	23	18	23	16
	Liquidity	13	13	13	13	13
	Level of debt	11	6	6	9	6
	Payment method	25	25	25	25	25
	Total Cost	550	393	448	486	550
	Risk management	50	50	45	45	40
	Evaluation of AIU	25	12	25	25	25
<b>Sub Total</b>	<b>Max 700</b>	<b>526</b>	<b>574</b>	<b>633</b>	<b>680</b>	
<b>Total</b>	<b>Max 1000</b>	<b>767</b>	<b>846</b>	<b>888</b>	<b>889</b>	

### CBA RESULTS

In order to validate the decision taken, it was applied the CBA method with the same criteria and using the information provided by the project manager by applying the seven steps proposed by Paz Arroyo et al. (2013). The first six steps organized in the tabular method (Table 2) and Figure 4 shows the seven-step, in which the Importance of

Advantage (IofA) vs. cost of the alternatives is analysed. An application developed in VBA for Excel® can be downloaded from [http://bit.ly/CBA\\_Excel](http://bit.ly/CBA_Excel).

The D alternative is the less favourable instead the result obtained by applying the traditional method. In Figure 4 can be seen that alternative D have a difference of almost 700 million of COP compared to the alternative C with, considered “the best” by CBA with more IofA.

Table 2: CBA results for steps one to six and the four alternatives (A to D).

	A		B		C		D	
<b>Years in construction</b>	40 years		20 years		8 years		6 years	
More is better	34 more years	12	14 more years	6	2 more years	3		
<b>Similar experience</b>	155,69 m2		202,65 m2		202,02 m2		21,77 m2	
More is better	133,92 m2 more	25	180,88 m2 more	30	180,25 m2 more	30		
<b>Bussines organization</b>	30 Professionals		40 Professionals		57 Professionals		15 Professionals	
More is better	15 Prof. more	20	25 Prof. more	25	42 Prof. more	30		
<b>Own equipment</b>	\$ 15,866,544.08		\$ 4,021,164.85		\$ 4,917,604.93		\$ 1,029,660.96	
More is better	\$ 14,836,883.12	30	\$ 2,991,503.89	10	\$ 3,887,943.97	10		
<b>ISO Certifications</b>	SIG		9001-18001-14001		9001		SIG	
At least one (1)			Have 3 certification	50	Have at least one	50		
<b>Makespan</b>	14,5 months		13 month		11 month		13 month	
Less is better			1,5 month less	40	3,5 month less	50	1,5 month less	40
<b>Equity</b>	22,55 smmlv		8,21 smmlv		33,33 smmlv		2,54 smmlv	
More is better	20,01 smmlv (2)	18	5,67 smmlv	10	30,79 smmlv	26		
<b>Liquidity</b>	2,18		3,2		4,47		2,5	
More is better			1,02 more	7	2,29 more	13	0,32 more	4
<b>Level of debt</b>	63,3		28,75		30,76		31,48	
Less is better			34,6 less	11	32,54 less	11	31,82 less	11
<b>Payment method</b>	0,3		0,3		0,3		0,3	
Less is better								
<b>Risk management</b>	\$ 26,943,619.57		\$ 8,554,684.62		\$ 20,564,512.99		\$ 2,040,078.90	
More is better	\$ 24,903,540.67	50	\$ 6,514,605.72	15	\$ 18,524,434.09	30		
<b>Evaluation of AIU</b>	0,41		0,48		0,33		0,23	
Less is better	0,07	10			0,15	15	0,25	25
<b>TOTAL IofA</b>	<b>165</b>		<b>204</b>		<b>268</b>		<b>80</b>	

Notes: (1) At least one of of ISO 9001-18001-14001

(2) smmlv is the spanish acronym of current legal minimum monthly salary

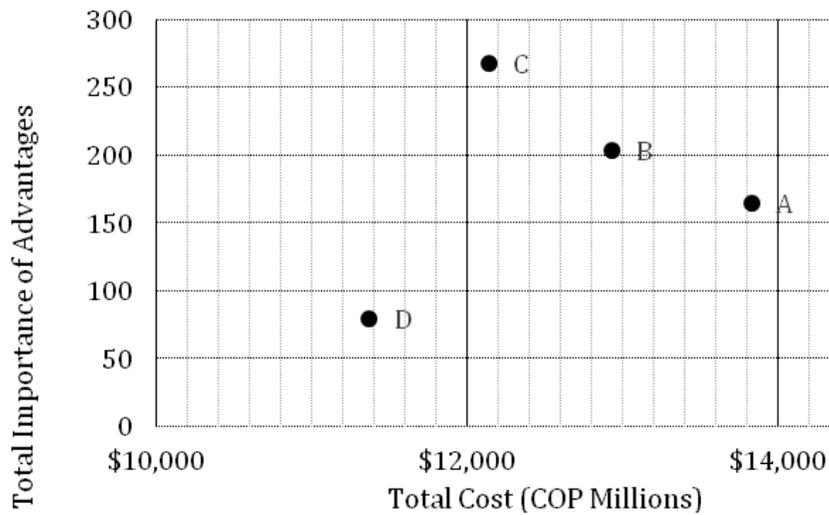


Figure 4: CBA results IofA vs. Total cost

## DISCUSSION OF THE RESULTS

This comparison allows analysing the decision in two different perspectives of the construction management: the management in the world of the cost and the management in the world of the value. These differences are reflected in the results shown in Figure 5.

The obtained results were in line with the expected: the best option applying the traditional method is the worst by applying CBA. In the CBA method, the differences among alternatives A and B decreases, while the alternatives C and D change in the order of preference. Additionally, the difference between C and D, increase from 1 point to 188 points or IofA showing that CBA considers that the best alternative is the one that provides more value to the project.

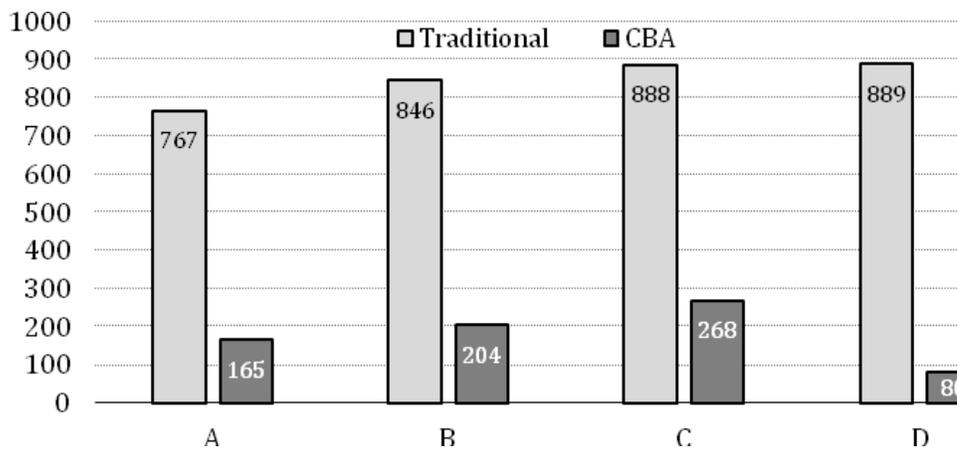


Figure 5: Comparison of results Traditional vs. CBA

Nevertheless, it is important to highlight that the alternative D, selected by the traditional method, only obtain advantage in a few factors by applying the CBA method,

being the worst ranked in: a) construction experience (in years), b) experience in similar buildings, c) business organization, d) own equipment, e) ISO certifications, f) equity, g) payment method, and h) risk management. This could be the reason why the problems arose and the project manager wondered if it was the right decision. The analysis of the results shows the benefits of CBA as an effective decision making tool compared to the traditional methods.

## CONCLUSIONS AND LIMITATIONS

The present research has analysed and compared the traditional method applied in Colombia for the selection and hiring of services provider with the CBA method in the process of select the structural contractor for an academic building in order to validate the decision made by the traditional method.

Therefore, the difference of the results among alternatives varies among methods; partly, as a consequence of not considering the cost as the main criterion. In addition, in CBA, the results of alternatives are easy to analyse, identifying the advantages, the factors in which is the difference and offer clearness to the criteria. Also, the traditional way in which decisions are taken is targeted on the result, disparaging the methodology to obtain it. Nevertheless, the making decision method is also important as the alternative selected.

Finally, it is considered that this case study does not evaluate if the factors were the correct and if the criteria was the right one; as a result, this is material for another research because it is not enough to use a different method of selection, it is also required to know how to use it. In this case, it implies to define correctly the factors, criteria and importance of each advantage.

## ACKNOWLEDGEMENTS

The authors would like to acknowledge the faith and support provided by the staff of the Campus manage from Los Andes University and all the research assistants of INGeCo (Research Group in Engineering and Construction Management) of the Universidad de Los Andes.

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