'CHOOSING BY ADVANTAGES' TO SELECT CONCRETE TASKS: A PROJECT TEAM'S PERCEPTION

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In most cases, the project team's decision-making outcomes is criticized for failing to meet client needs when working with concrete task. The purpose of this study was to examine how Choosing by Advantages (CBA) would affect the choice of concrete alternatives for civil engineering and building projects. Case study research design was used in this study and three case projects were identified to discover the project team's decision-making process when choosing concrete type in civil engineering and building projects. The research question is, '*how can the project teams use CBA decision-making mechanism to choose a concrete task?'* The project teams are the key driver of CBA mechanism when choosing concrete type from two alternatives: ready mixed concrete and site batched concrete. The results showed that ready-mixed concrete has less probabilities of causing concrete defects and rework when used or applied per the correct specifications or methods which are detailed in the structural or engineering drawing. CBA mechanism could be introduced and applied by the project teams during the initial stage of the construction project. The study proposes that the project teams should try CBA to improve their decision-making process on site when working with concrete. The CBA Frame Model would help the project teams to make sound decision when choosing alternatives.

Keywords: Choosing by Advantages, Concrete, decision-making, Performance, Project teams

INTRODUCTION

Project performance is influenced by the project teams decision-making outcomes in several ways: positively or negatively. A negative influence implies the possibility of poor performance. Emuze and Smallwood (2012) explains that South African construction is subject to poor project performance because of the project team's decision-making outcomes. The project teams often fail to address the subject of poor performance broadly in the construction activities and stages (Mollo, Emuze and Geminiani, 2016). Poor performance is dependent on the project team's decisions related to time delays, change in design, cost overruns, payment problems, material shortage and defects and rework (Meng, 2012). The results of poor performance may be generated either externally or internally. External factors pertain to weather conditions, unforeseen site conditions, market fluctuation and regulatory changes, while internal factors pertain to the outcomes of the project team's decisions adopted for the project (Meng, 2012).

During the planning stage of the project, the project team examines and calculates the performance of the required design and construction activities. It is at the planning stage that the utility of Choosing by advantages (CBA) is evident. The CBA mechanism is a decision-making system that comprises methods for almost all kinds of decisions during the construction process regardless of the scope of work (Arroyo, Tommelein and Ballard, 2014). In specific terms, the evidence of constraints at various stages of the project necessitates the use of CBA at the planning stage (Abraham, Lepech, and Haymaker, 2013). For example, the scope of work in a project may require special understanding that is underpinned by the involvement of highly informed consulting professionals and construction teams (Zhang, 2013). Previous studies illustrate that CBA is conducted through case study project for example; Arroyo, Tommelein and Ballard (2014), and Karakhan, Gambatese, and Rajendran (2016), the analysis from both studies were discovered through case projects.

The choice of actions to be taken by the project teams impacts on the project outcome. Parrish and Tommelein (2009) stated that when determining the advantages of the construction process alternatives to improve performance, subjective judgement should not be ignored because the advantages might rest on the subjective. It is evident that projects are challenged by poor performance influenced by the project team's decisions.

In this study, Tabular Method of Choosing by Advantages (CBA) was adopted to understand the project teams decision-making process and to overcome the challenges of choosing a concrete type between ready mixed concrete and site batched concrete, with the aim to reduce and eliminate defects and rework related to concrete on projects.

CASE EXAMPLES OF DECISION-MAKING MECHANISMS

Baron (2008) described decision as an act of choosing between two or more possibilities of action, of what to do or not do. Decisions are executed by the project team to achieve project goals, and they are grounded in the belief of the project team actions regarding the achievement of project goals. The project team constantly need to make project decisions and the need to make project decisions arises out of the fact that knowledge of relevant existing facts is inadequate and that the future of the project is uncertain (Senior, 2012). Ariely (2009) said the project team often struggle to choose between two actions that are similarly attractive.

According to Young, Hosseini, and Ladre (2016), the state of construction industry is changing from time to time and the project team are expected to make project decisions which will meet the need of the project. The project decisions could be improved through the principle of lean thinking (lean construction), due to the reasons that lean thinking provides comparatively more autonomy in the project decisions and enrich the project team by distributing the decision-making, multi-skilling and pursuit perfection (Senior, 2012). Furthermore, lean construction makes the project team to better understand a project decision-making process through CBA, which is a component of lean construction (Schöttle, and Arroyo 2016). CBA is a decision-making method which weights the importance of advantages between the alternatives of the project (Suhr, 1999).

CHOOSING BY ADVANTAGES (CBA)

CBA is a decision-making method that assists project parties in deciding a course of action among competing alternatives (Arroyo, Ballard, and Tommelein, 2014). The idea of CBA began in the United State of America (USA) in the 1980's by Suhr (1999), but it is only recently making way into the Architecture, Engineering and Construction (AEC) industry (e.g. Parrish and Tommelein 2009, Lee, Tommelein, and Ballard 2010, Abraham, Lepech and Haymaker 2013, Arroyo, Tommelein and Ballard 2014, Schöttle, and Arroyo 2016,). CBA mechanism is characterized by the following terms; alternative, factors, criterion, attributes, advantages and importance of advantages (Suhr, 1999).

Table 1: CBA Vocabulary

Terms	**Definition**
Alternative	Either one or more project decision adopted by the project teams in terms of the use of materials, and other project inputs
Factors	A section, parts, or mechanism chosen from the alternative. When assessing performance, factors should represent period, cost and quality.
Criterion	A policy or decision law regulated by the project teams. A 'must' criterion symbolizes circumstances each alternative must please. A 'want' criterion symbolizes favorites of one or several decision-makers.
Attributes	Type of quality, results or characteristics of one alternative
Advantages	The beneficial factors between alternatives in the project

Source: Arroyo et al. (2014).

Abraham *et al.* (2013) states that CBA is one of the best decision-making system, because it differentiates decisions relating to money and non-money. In this study, CBA is introduced through Tabular Method (TM), which is suitable for complicated projects, mostly when the project decisions comprise of multiple alternatives, when there are different information's to be judged and the entire project teams are involved in the decision-making process (Arroyo *et al.*, 2014). For all three case projects, the project teams were the key drivers in the concrete decision-making process between two alternatives.

Figure 1 highlights the CBA Frame Model that constitute the outline of the research process. Step 1 in the figure, which is a green boundary, represent the project team's problems about poor performance influenced by concrete defects and rework as the outcome of the project team's decisions when placing or casting concrete. Step 2, which is the Yellow boundary, represent the decision-making methods that provided the guidance to reduce and eliminate concrete defects and rework. The subsequent steps (3,4,5 and 7), which is the blue boundaries, were carried out or developed by the project teams, while the CBA practitioners analyses the results as outlined in Step 6,8, and 9. These constitute the red boundaries carried out by the researchers. These steps were also examined and discussed by the project team.

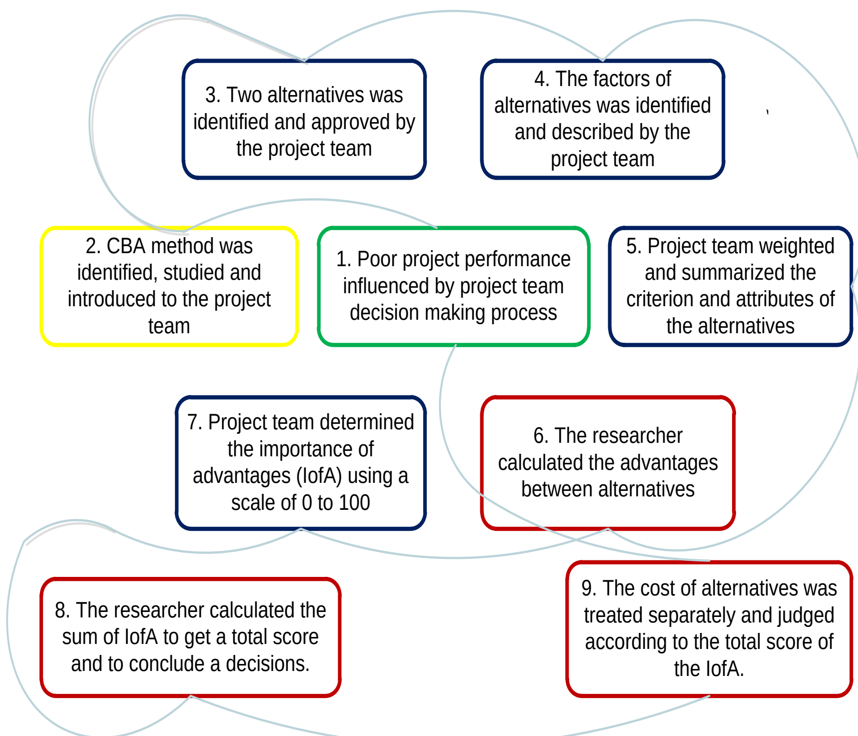

Figure 1: CBA Frame Model of Choosing an Alternative

RESEARCH METHOD

This study is based on the case study research design, because it supports the nature of the research question, which asked the 'How' questions, *'how can the project teams use CBA decision-making mechanism to choose a concrete task?'* as illustrated by Yin (2014). In this case, case study design helped to gain an in-depth understanding concerning the project team decision-making process when choosing a concrete type. The case study research design was chosen because it allowed the researcher to look at a phenomenon in context as recommended by Yin (2014). The design is defined as the practical reviews that explore an existing issue in detail and within its actual setting, particularly when the border between phenomena is not apparent (Yin, 2011). The design of this study is a multiple case study due to the three case projects that were conducted in Bloemfontein, South Africa. The projects involve:

- Case project 1*: New North-Eastern Waste Water Treatment Works (civil engineering project),*
- Case project 2: *N8 Road Rehabilitation: Bloemfontein to Sannaspos: Bridge no, B286 (A & B): Bloemspruit River Bridge (civil engineering project)*, and
- Case project 3: *Construction of MOTHEO TVET Artisan Development Academy (building project.*

The projects were selected based on their nature, which require extensive use of concrete. The unit of analysis determined the research design and identified the type of data which were collected as described by Yin (2014). The study was conducted between June and September 2016 as part of the master's study. A semi-structured interview was carried out among 22 project team members, which were made up of the contractors and consulting engineers for all three cases. Cross case analysis was used to analyze the data as recommended by Yin (2014). Therefore, the project team's decision-making process when choosing a concrete type was the unit of analysis for this study.

RESULTS ON CBA: CONCRETE TYPE FROM CASE PROJECT 2

This study determines the procedures, which were followed to explore the project team's decision-making when choosing concrete type in case project 2. The nature of the project for case project 2 was civil engineering project and the title of the project: *N8 Road Rehabilitation: Bloemfontein to Sannaspos: Bridge no, B286 (A & B): Bloemspruit River Bridge*.

Figure 2 shows the picture of the project. The study focused on the project teams decision-making process during the bridge construction. The data for this case study were collected through semi-structured interviews, a total number of eight (8) interviews were conducted for this case: two construction managers, two foremen's and four resident engineers (RE). However, the client did not form part of the interviews because the consulting engineers managed the project for the client, as the principal project agent. The client was not part of the teams making concrete decisions. The details of the project were retrieved from South African National Road Agency South Africa Limited (SANRAL) database.

Figure 2: Bridge construction

The application of CBA mechanism was introduced to the project team through discussions and questions supported by presentations. In addition, the relevant information for the decision-making process, the process for obtaining the information, and assumptions behind the data were presented. From the discussions, the project teams managed to identify two concrete alternatives (ready mixed concrete and site batched concrete) and articulated relevant factors, criterion and attributes of the concrete alternatives as highlighted in Table 4. The CBA mechanism proved to be suitable decision-making mechanism to be adopted by the project teams when making project decisions, but they expressed that it would be difficult to introduce this mechanism in their project because of the construction procurement method that is dominant in South Africa. The design-bid-built procurement method that is mostly used in South Africa ensures that the construction team (contractors) does not form part of the project teams until project implementation stage. However, for this case project, the teams had already chosen ready mixed concrete for their project.

STEPS TO INTRODUCE CBA

The procedures or steps to introduce the application of CBA mechanism has been illustrated in Figure 1. The CBA Frame model regarding this project is explained as follows: step 1: Classifies the project team's problems. For this case, it was discovered that project teams decision-making process when choosing a concrete type often lead to concrete defects and rework. In step 2: The decision-making method was selected, CBA mechanism was studied, and introduced to the project teams. In Step 3: The project teams identified two concrete alternatives: ready mixed concrete and site-batched concrete. In step 4, the project teams named and described 7 relevant factors shown in Table 2.

Table 2: Description of Factors

Factors	Description
Quality Control	Are the procedures intended to ensure that a mixed concrete adheres to the mix design and compressive strength designed by the structural engineers
Consistence	Is the mobility of the concrete, is related to the wetness of the concrete mixture
Handling concrete	Refers to the methods adopted on site activities relating to concrete transportation, placing, compaction, finishing and curing
Concrete strength	Is the capacity of concrete material to withstand loads tending to reduce size, as opposite to tensile strength
Formwork	Is the temporary structure used to contain poured concrete until it settles to adopt the designed shape
Labourer	Are workers employed to work with the concrete task on the project
Health and Safety (OHS)	Is the law which entitles the workers to work in environment where risks to the OHS are properly controlled

In Step 5: The project teams analyzed and defined the criterion and attributes of each factors relating to the concrete alternatives as indicated in Table 4. The CBA practitioner adopted the information (results), which were presented from step 1 to step 5 to conclude step 6 and 8 by choosing the advantages of attributes within alternatives and in step 7, the importance of advantages (Imp) was determined by the project teams through a scale of 0 to 100 as indicated in Table 3.

The Importance of advantages score (IofA) is determined by the project teams through a scale of 0 to 100. Where 100 is given to the most important advantages. To give the IofA to the other advantages, the CBA practitioner compared the advantages (Adv) to the most important advantage (Imp). The project teams calculated the IofA score by comparing criterion of the factors with the attributes of the factors. Table 3 shows an example which was used to calculate the IofA score. In step 9, the CBA practitioner evaluated and compared the cost of ready mixed concrete and site batched concrete with the project teams as recommended by Schöttle and Arroyo (2016), that cost of the alternatives should be analyzed separately.

Table 3: Importance of Advantages (IofA) Score

		Alternative 1: Ready mixed concrete	Alternative 2: Site batched concrete
Factors	Quality Control		
Criterion	Easier is better		
Attributes		The slump test and cube test are taken before placing the concrete	Concrete mix design and aggregates must be inspected before batching and slump test and cube test must be taken before placing the concrete
	Interviewees 1&2: IofA Score (0 to 100)	40	10
	Interviewees 3: IofA Score (0 to 100)	50	15
	Interviewees 4: IofA Score (0 to 100)	20	23
	Interviewees 5, & 6: IofA Score (0 to 100)	30	12
	Advantages (Adv)	(40+50+20+30)/4 = **35 Imp**	(10+15+23+12)/4 = **15 Imp**

Note, the highlighted attributes have the advantage over the other attributes of the alternative. CBA mechanism is determined by the advantages between alternatives. The preferred attribute is determined by the advantage between attributes of two alternatives. CBA mechanism compares advantages between ready mixed concrete and site batched concrete and allocates scores only to the alternative that shows an advantage in a factor as illustrated in Table 4. The advantages between alternative is calculated per this formula:

A= (PA-LPA)

A: Advantages

PA: Preferred Attributes

LPA: Least Preferred Attributes

Equation: Advantages Calculation Formula (adapted from Arroyo *et al*, 2014)

An example of how the advantages between alternatives were calculated:

Factors: Labourer

Criterion: Fewer is better

Attributes: Alternative 1: *5 labourer are needed to work the concrete per cube*.

Alternative 2: *10 labourer are needed to work the concrete per cube*.

Calculation of the advantages for Alternative 1.

A = (PA-LPA)

A =?

PA = 5 Labourer

LPA: 10 Labourer

A = (5-10)

A.= 5Labourer

Calculation of the advantages for Alternative 2

A = *(PA-LPA)*

A =?

PA = 10 Labourer

LPA: 10 Labourer

A = *(10-10)*

A.= 0 Labourer

The calculations and the IofA score (Table 4) are grounded based on the criterion rule of the factors, in this calculations example fewer labourer are better. This is the reason why alternative 1scored better result than alternative 2 judging from the alternatives attributes.

Table 4: Choosing Concrete type

		Alternative 1 **Ready mixed concrete**	**Alternative 2** **Site batched concrete**
Factors	**Quality Control**		
Criterion	Easier is better		
Attributes		Concrete Quality is controlled by taking the visual approved concrete test (slump and cube test)	Concrete Quality is controlled by studying the concrete materials (aggregates, water, cement etc), next testing the concrete strength

Advantages		Adv.: Better than Site-batched	Imp: 35	Adv.: No	Imp: 15
Factors	**Consistence**				
Criterion	Faster is better				
Attributes		The ready mixed truck takes 5 minutes to be parked close to the crane		The truck will take 15 minutes from the batching plant to get to the site	
Advantages		Adv.: 10 min	Imp: 50	Adv.: 0 min	Imp: 20
Factors	**Handling Concrete**				
Criterion	Fewer is better				
Attributes		It takes 40 minutes to handle the concrete per six cubes		It takes 55 minutes to handle the concrete per six cubes	
Advantages		Adv.: 15 min	Imp:45	Adv.: 0 min	Imp:15
Factors	**Compressed strength**				
Criterion	Higher than 30 Mpa				
Attributes		30 Mpa concrete strength are crushed 7 days after placement		30 Mpa concrete strength are crushed 7 days after placement	
Advantages		Adv.: Cannot be compared	Imp: 40	Adv.: Cannot be compared	Imp: 40
Factors	**Formwork**				
Criterion	Stronger is better				
Attributes		The formwork shutter is aligned and stiffened to support the concrete		The formwork shutter is aligned and stiffened to support the concrete	
Advantages		Adv.: Cannot be compared	Imp: 100	Adv.: Cannot be compared	Imp: 100
Factors	**Labourer**				
Criterion	Fewer is better				
Attributes		5 labourer are needed to work the concrete per cube		10 labourer are needed to work the concrete per cube	
Advantages		Adv.: 5 labourer	Imp: 50	Adv.: 0labour	Imp: 25
Factors	**Health and Safety**				

Criterion	Lower risk is better				
Attributes		The risk of health and safety to workers is medium		The risk of health and safety to workers is medium	
Advantages		Adv.: Cannot be compared	Imp: 30	Adv.: Cannot be compared	Imp: 30
Sum of IofA			**350**		**245**

STEP 9: CONCRETE COST DATA EVALUATION

The decision-maker compared the IofA vs. cost of the alternatives (CoA) in Figure 3. Figure 3 illustrates 30 mpa concrete price comparison between site-batched concrete which is estimated at $ 152.42per cubic meter (m^3), and ready-mixed concrete which is estimated at $ 209.59per m^3. This are the average concrete rate per m^3 in Bloemfontein between June and September 2016. Figure 3 also shows that site-batched concrete is less economical when compared to ready-mixed concrete. However, the project teams support their decision to choose ready-mixed concrete because they believe that it reduces cost in a long run, while site-batched concrete requires or compels the contractor to employ a concrete specialist; also, there is often a problem relating to material theft, materials wastage, and more labourer are employed on site. These factors need money to be maintained and ready-mixed concrete helps the contractor to avoid this cost. The ready-mixed concrete reduces the construction risk for the contractor because the supplier is responsible for the concrete delivered or supplied to the site. The ready mixed concrete is subject to South African National Standard (SANS) 878 requirement, and the concrete supplier was approved by South African Ready-mix Association. SANS 878 compel the ready mixed company to transport the concrete to the site within the permissible range of slump for a period of 30 minutes from the arrival at the site.

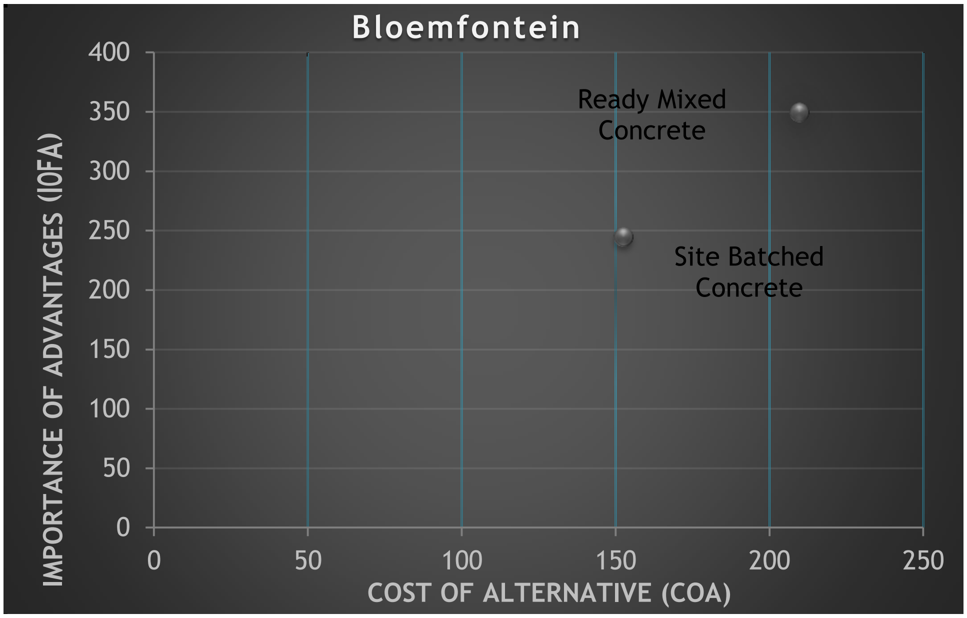

Figure 3: IofA vs. CoA

DISCUSSION

Emuze (2012) emphasize that project performance is very unsatisfactory and is often influenced by the project team decisions outcomes. The reviewed literature in this study presented evidence that project team decision outcomes often leads to poor performance, especially when working with concrete task. Concrete is a critical material which must be chosen by a concrete specialist or professional who has gained extensive knowledge and experience in the construction industry. The outcomes of the project team decisions when choosing a concrete type often causes defects and rework related to concrete project, which can be eliminated through CBA mechanism. Karakhan *et al.* (2016) described CBA as an element of lean thinking adopted by the project teams to improve their project decisions to sound decisions and congruent to eliminate concrete defects and rework. The application of CBA was based on a well-defined vocabulary relating to the two concrete alternatives (ready mixed concrete and site batched concrete), which were determined by the project teams as illustrated by Suhr (1999).

The case study analysis shows that CBA could help the project team to make sound decision when choosing concrete alternatives. The application of CBA is not influenced by the cost of alternatives rather the importance of advantage scores. This is the reason why ready mixed concrete is preferred more than site batched concrete even though site batched concrete is less economical when compared to ready mixed concrete. The case analyses further show that ready mixed concrete has less chances of causing concrete defects and rework when compared to site batched concrete, if applied correctly.

CONCLUSIONS

This study has confirmed the application of CBA mechanism when making project teams decisions to improve project performance. This study provides insight about the rationale over the choice between ready mixed concrete and site batched concrete by providing questions that the project teams should ask in discovering the best alternatives. The project teams identified and described factors, which influenced concrete works either positively or negatively, depending on the project teams work experience. The concrete alternatives were judged per the IofA score rate issued by the project teams. It was discovered that ready-mixed concrete had a better score than site-batched concrete. The cost of the concrete was judged separately as recommended by Legmpelo (2013), that the goal of the project teams is to determine the best alternatives, which was ready mixed concrete without over emphasizing initial cost of the concrete and that concrete cost should be addressed after the implementation of CBA. This realization resonates within the CBA literature.

Furthermore, the project teams stated that even though site batched concrete is less economical when compared to ready mixed concrete, they favor the IofA score. Previous CBA studies already shows that CBA continues to be a preferred decision-making method when choosing the best alternative from multiple alternatives. So, the application of CBA should be adopted during the pre-tendering phase of the project due to the reason that critical decisions are taken during the design of a project. This exploratory work, however, needs to be conducted on a longer period to examine, analyze and define the CBA Frame Model in detail.

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