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TEACHING CHOOSING BY ADVANTAGES: LEARNINGS & CHALLENGES

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ABSTRACT

Choosing by Advantages (CBA) is a promising lean tool for fostering collaboration, value generation, cost optimization and reduction of waste in the design phase of construction project. This paper describes the experience with teaching of this tool to the students of masters programme in Construction Engineering and Management in an Indian university. As part of the exercise of Choosing by Advantages, the students were asked to select design problems for a construction project. The students group comprised of engineers and architects, which facilitated the role play of real life industry stakeholders - contractor, designer and client. A participant observation of the role play was conducted to understand their learning from this CBA exercise. The analysis indicated that the students learned about necessity of collaboration, design complexity and systematic decision making. Although, the concepts can be articulated in much better manner after overcoming the cognitive barriers and perceptions about prevailing construction industry environment.

KEYWORDS

Lean construction, choosing by Advantages (CBA), collaboration, action learning

INTRODUCTION

The fundamental premise for improving workflow and processes in a construction project with lean philosophy hinges on collaborative efforts among stakeholders, value creation for the client and waste removal(Howell 1999). There are different tools that have been devised for bringing in transformational changes in the design, construction and operation phases of a construction project(Ballard et al. 2002). The application of lean tools and techniques in the construction phase has been more widespread than in its design phase (Munthe-Kaas et al. 2015). Among the different tools for lean design management, the Choosing by Advantage (CBA) method holds great potential owing to imbibing and/or

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forcing collaborative processes in the design process and value maximization process for the client. (Suhr 1999). It is thus important to elucidate the benefits derived from lean philosophy to emerging construction managers such as students of construction engineering and management programme. This will provide an impetus to the propagation of lean ideals in the construction industry. In this context, this paper discusses the learnings and challenges in teaching CBA. This paper comprises four section. The second section provides an overview of CBA method and its application in the construction industry. The research setting is discussed in the second section. The third section provides a background of research methods while learnings and challenges are discussed in the fifth and sixth sections respectively. The paper concludes with the seventh section.

CHOOSING BY ADVANTAGE

The CBA is a collaborative, visual and transparent decision making system developed by Jim Suhr (Suhr 1999). There are specific terms: factor, criteria, attribute and advantages, known as CBA vocabulary. Arroyo et al (2013)described terms in the context of the construction industry as follows:

- Alternatives Two or more construction methods, materials, building designs, or construction systems, from which one or a combination of them must be chosen.
- Factor: An element, part, or component of a decision. For assessing sustainability, factors should represent economic-, social-, and environmental aspects. It is important to note that CBA considers money (e.g., cost or price) after attributes of alternative shave been evaluated based on factors and criteria.
- Criterion: A decision rule, or a guideline. A ‘must’ criterion represents conditions that each alternative must satisfy. A ‘want’ criterion represents preferences of one or multiple decision makers.
- Attribute: A characteristic, quality, or consequence of one alternative.
- Advantage: A benefit, gain, improvement, or betterment. Specifically, an advantage is the beneficial difference between the attributes of two alternatives.

The above definition shave been followed in the CBA exercise conducted in this study. CBA has been discussed widely in the lean community –both among practitioners and academicians. Parrish and Tommelein(2009)have discussed the application of CBA for selecting a design for steel reinforcement. Jim Shur and Paz Arroyo have encouraged the application of CBA method among practitioners through workshops and training. Arroyo et al. (2014) have compared the CBA method with the widely used Weighting Rating and Calculating (WRC) method. Their comparison is based on selection of a structural system for a campus residential building and it shows that although both methods lead to same decisions, the CBA method creates transparency and builds consensus in the decision making process. These authors have also showcased application of CBA method for selection of ceiling tiles from the perspective of global supply chain (Arroyo et al. 2013).

CBA is one of the lean methods / tools that can be applied in the design stage of a project. There are many such potential tools that are useful across lifecycle of construction project and it is very important to impart knowledge about these tools to novice construction professionals. The academicians must ensure integration of lean philosophy into the existing curriculum of civil engineering programs in India. The authors have performed an analysis of the curriculum of a master's programme in construction engineering and management in India, in terms of the incorporation of lean construction courses. The analysis showed that most academic institutions do not have courses or lessons on lean construction related topics. In this context this paper shows how lean tools can be included in the civil engineering curriculum in order to enhance learning in this area.

RESEARCH SETTING

The CBA method was taught to the students of M.Tech (Construction Engineering and Management) programme at CEPT University in India. This programme lasts two years and spans four semesters. The first three semesters have a studio course which becomes a central core for a particular semester. The studio course aims to bring real life problems into the class room and equips students to solve these problems with the application of theoretical concepts. In reality, it attempts to bridge the gap between theory and practice. The first semester of this programme includes a studio named "Construction Project Formulation and Appraisal". The aim of this studio is to equip students with necessary knowledge and skills for performing appraisal of construction project from the viewpoint of finance, economics, design and engineering.

In our study, there were 23 students in this studio module. Of these 23 students, 7 students had prior educational degree (Bacherlor's) in Architecture (known as B. Arch) while the rest had an undergraduate degree in Civil Engineering (known as B.E/B.Tech – Civil). Many of these students had work experience of 2 to 3 years. Of these 23 students, six groups were created and each of these groups had a student with BArch qualification and with work experience. The group were designed to foster cross learning among students of different educational backgrounds, to hasten the learning trajectories of students without work experience, and to transition students with work experience into the learning mode by raising questions / queries on set practices in construction industry.

The instructors provided a list of potential projects to be appraised in this studio. This list contained projects from varied sectors like solid waste management, roads, water supply, sports facilities and real estate. These projects were either in the proposal stage, indicated as in pipeline stages by government departments or private developers, or were at the preliminary stages of construction. The projects were allocated to the groups based on their interests. The groups were expected to perform appraisal of assigned project by collection and analysis of primary as well as secondary data. The primary data was collected from interviews with stakeholders like project proponents, public sector organizations involved in approval and implementation of project, industry groups, think tanks and non-governmental organizations. The secondary data was in the form of traffic survey, minutes of meeting, census and demographic parameters, governmental policies

and contracts. The following appraisals were typically carried out by each group: demand and market assessment, technical analysis, legal compliances, project conceptualization and planning, financial analysis, technical analysis, project structuring and procurement strategy, stakeholder analysis, environmental impact assessment, risk analysis and project controls. Based on the availability of primary and secondary data, each group performed in-depth analysis or assessment of a few topics, although, the instructors ensured breadth in terms of areas to be typically analysed. Following is the list of projects selected: Four laning of Mehasana - Himatnagar highway, Vadodara Exhibition and Convention Centre, Sea water based desalination plant for industrial water supply in Kutch region, Redevelopment of Motera stadium and Maritime museum at Lothal.

To begin with the student groups investigated the project characteristics covering factors like location, transport connectivity and stakeholders associated with the project. These factors helped in carrying out locational analysis that focused on advantages and disadvantages associated with actual project site as well as other potential sites. After completion of this analysis, the studio discussion focused on technical analysis. It comprised development of design brief, proposed design and target value design. The students collected information pertaining to bylaws, standards and specifications, site characteristics and guidelines relevant for design development. They also analysed the design features of existing projects having similar scale and area. For example, the group working on Vadodara Exhibition and Convention Centre understood the spatial requirements (area and capacity) pertaining to conference hall, auditorium, open art gallery, open lawn and other facilities. Further, this group studied the bylaws of Vadodara Municipal Corporation and Government of Gujarat, structural codes for steel and reinforced cement concrete (RCC) members and operation and maintenance guidelines. The design features of existing Mahatma Mandir Convention and Exhibition Centre at Gandhinagar in Gujarat, India were studied. At the end of this exercise, the group developed a design brief of the project.

The student groups presented the design brief and feedback was provided by instructors for further refinement. The design brief was also shown to domain experts for comments and feedback. Further, the students were told to identify design problems, in consultation with the instructors and domain experts, related to their respective projects. There were different design problems faced in the project, however, the student groups selected the key problems that had implications from the perspective of functionality and performance of project, and cost implications to the overall project. Subsequently, the student groups identified alternatives for each design problem. These design problems are shown in Table 1.

At this stage, the concepts of "Target Value Design (TVD)" and "Choosing by Advantages (CBA)" were introduced to the students in the form of class room presentation and discussion, and circulation of reading material for improving conceptual understanding and application of these concepts. The concept of "Target Value Design" was discussed briefly while elaborate discussion was conducted for "Choosing by Advantages (CBA)" method. The reading material comprised of many papers published in previous IGLC conferences, discussing examples of CBA and TVD (Arroyo et al. 2013; Arroyo et al. 2014; Emuze and Mathinya 2016). The exercise of CBA in this studio

was used to drive learnings on the front of collaboration, communication, problem solving and value maximisation in the design process. The steps for CBA mentioned by Arroyo et al (2013) were followed: 1) identify alternatives, 2) define factors, 3) define must / 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. A role play was introduced in conducting this exercise.

Table 1: Design Options

Project	Design Problem	Design Options
Four laning of Mehsana Himatnagar Highway	- Choice of recycled material in sub base layer - Choice of street lights - Choice of crash barrier	- Reclaimed asphalt, steel slag, glass, plastic - Solar powered LED lamps, Sodium Vapour Lamps, Mercury Vapour Lamps - W-Beam Metallic, Concrete, Cable
Vadodara Exhibition and Convention Centre	- Choice of material for partition walls - Choice of sewer drains - Choice of pavement for parking	- Brick, precast hollow crete, gypsum board - Hume, HDPE, DI - Hot mix asphalt, precast paver blocks, concrete
Desalination plant for industrial water supply in Kutch region	- Choice of energy source for the desalination plant - Choice of pump technology - Choice of material used for pump manufacturing	- Non-renewable, photovoltaic, wing Membrane - Reverse osmosis, ultra filtration, nano filtration - Stainless steel, carbon steel, cast iron and copper nickel alloy
Redevelopment of Motera Stadium	- Selection of stadium roof material - Choice of parking alternatives	- PVC, PTFE (Tefloncoated fibre glass) - Surface, Conventional multilevel, automated multilevel
Integrated solid waste management project for Vadodara	- Choice of roofing material - Choice of pavement of transfer station - Choice of liner system	- Steel roof, eco roof / vegetative roof, modified bituminous membrane, foam filled composite panels - RCC pavement, post tensioned RCC pavement, bituminous flexible pavement - Compacted Clay + geo membrane liner system, Geo bentonite + geo membrane liner system
Maritime museum at Lothal	- Choice of cladding material - Choice of parking lights - Choice of flooring	- Metal, stone, glass fibre reinforced, glass - High pressure sodium vapour lamps, energy efficient fluorescent tabular lamps, LED lamps - Vitrified tile, ceramic tile and wooden

The members of each students group were divided into three roles: client, contractor and designer. The role of designer was assigned to students having bachelor's degree in architecture while students having work experience and no experience played the roles of contractor and client, respectively. The rationale behind the assignment of these roles was to harness educational background and experience of a student to play the role effectively. For example, the student with a work experience can foresee and visualize the construction process of a project easily and effectively. Each student playing a specific role in a group was told to identify the factors. Subsequently, a discussion was initiated by the instructors about the design problem and appropriate factors for comparison and decision making. The students were asked to paste sticky notes on the white board mentioning the name of factors and describe them to other group members. The students identified the factors having similar understanding and listed these factors separately on the white board. Further, the student playing the role of owner took the centre stage and students playing the role of designer and contractor addressed two questions: 1) Did the owner fail to take any factor into consideration?, and 2) Why it is important to consider the factor proposed either by designer and contractor in the design process. The instructor facilitated this consensus building exercise to ensure that the most relevant factors make way to the final list (Refer Figure 1).

The students were asked to make the final list of factors in an excel spreadsheet, and decide on "must have" or "want to have" criteria for each factor. The students looked for availability of standards and guidelines relevant for each factor, which would qualify the criteria as "must have". In case of unavailability of these documents, the students arrived at the "want to have" criteria in consultation with industry professionals and discussion among team members. After describing the criteria for each factor, the attributes and advantages for each alternative were mentioned by the students in the spreadsheet (Refer Figure 2).

The student members representing owner, contractor and designer deliberated on the most important advantage offered by each alternative and finally the selected advantage was highlighted in the spreadsheet. This deliberation involved perspectives of student playing role of designer and contractor on how advantages offered by specific alternative creates value maximization for client and the student playing the role of client was required to provided his/her opinion about the perspectives offered. A scale from 0 to 100 was used for scoring importance of the advantages; the most important advantages were scored first and it is followed by scoring of remaining advantages. The total of importance score of advantages for each alternative was calculated by summing up the importance score of each attribute. Finally, the students attempted to plot the total importance of advantages against the cost for each alternative.

RESEARCH METHOD

This participant observation method has been recognized as a most important core research method, with the strength of "collecting data first-hand". The instructors involved in this CBA exercise played multiple roles. Firstly, they played the role of "teacher" with the primary objective of teaching the application of CBA in the design

process at hand. Further, they played the role of "facilitator" for the role play exercise wherein collaboration and communication was facilitated. From the perspective of research method, the instructors also played an important role of "observer". Baker(2006) has described various roles of observer as Nonparticipation; Complete Observer; Observer-as-Participant; Moderate or Peripheral Membership; Participant-as-Observer, Active Participation, Active Membership; Complete Participation;and Complete Membership. Based on this typology, the role play by the instructor seems to equate to "Moderate or Peripheral Membership" wherein the researcher helps to "maintain a balance between being an insider and an outsider, between participation and observations" (Baker 2006).

Figure 1: Discussion on advantages of alternatives

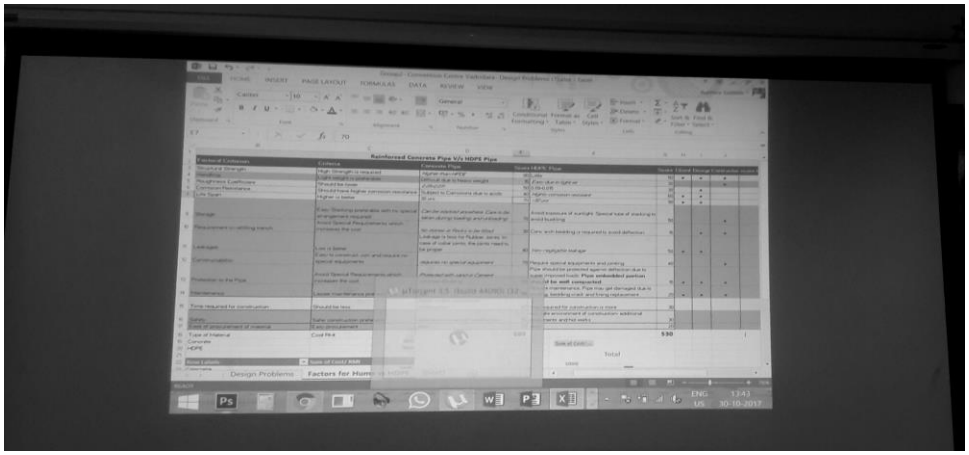

Figure 2: Evaluation of cost data and selection of alternatives

The objective of the CBA exercise was to investigate the extent of learning in the areas of 1) benefits of early involvement of contractors in the design process, 2) collaboration between designer and contractor for delivering value to the client, 3) striking balance between value, cost and advantages related to design option. The

instructor played the role of an "insider" and participated in the CBA exercise to guide the role play and entire process for maximizing the learnings in the mentioned areas. At the same time, the researcher became an "outsider" and observed the extent to which the learning actually occurred. The information pertaining to extent of learning was gathered with the help of questions that were asked to the students and observations during the CBA exercise. The questions focused on extent of learning on the fronts mentioned earlier. The instructors noted the comments of students, provided in response to the questions, during the CBA exercise and suggestions given by students. The comments along with observational notes for each student group were collated and analysed to gain insights into the learnings and challenges in implementation of CBA exercise in classroom environment.

LEARNINGS

The key learnings by conducting CBA exercise is as follows:

IMPROVED UNDERSTANDING ON NECESSITY OF COLLABORATION IN DESIGN PROCESS

The advantages of collaboration between designer, contractor and client in the design process became evident with the role play of the students. Typical notion of design process being driven and steered by designers with minimal or lack of inputs from contractor came under scrutiny during the preparation of the final list of factors for selection of design options. The journey from protecting factors identified by each student representing a specific role, to arriving at final list helped the students to appreciate the collaborative nature of design process. During the presentation of factors identified by each student, representing a specific role, the students became aware of different perspective of design problem. For example, attributes like constructability, sourcing of materials / technologies / equipment and operation and maintenance were commonly put forth by student playing role of contractor. The students playing the role of client and designer understood need to consider these aspects at the design stage. Similar scenario was observed with the factors identified by the students playing the role of contractor and client. This laid the foundation for consensus building required for arriving at the final list of factors. While students were relatively open to "let go" the non-relevant factors and / or revise the factors identified by them, the major breakthrough of CBA exercise happened at this stage wherein students realized the importance of defining value for the client and participation of key stakeholders – client, designer and contractor in value identification and maximization process.

EASING COMMUNICATION FLOWS AMONG DESIGNER, CLIENT AND CONTRACTOR

The students understood that identification of factors, advantages and criteria is just half the journey and it is important to communicate their relevance to other key stakeholders and arrive at conclusions. During the CBA exercise the student was expected to bring perspective and analysis in line with the assignment role, and communicate the relevance

of specific factor in line with value creation perceived by other members. It was observed that the students took extra efforts by collecting facts and figures related to a design problem for playing a role assigned to them and learned to communicate this information from different perspectives. The flow of communication among different disciplines during the design process is cornerstone for reducing waste in design and engineering process. In this context, the learning of students, gave them first-hand experience with not only effective communication but also in ingraining of diverse perspectives helps in arriving at design solution.

ITERATIVE AND COLLABORATIVE NATURE OF VALUE DEFINITION

The lean construction indicates that the constructed facility should deliver value to the client. After listing of factors on the white board by each student representing a particular role listed the factor, the discussions that eschewed focusing on how a particular factor adds value to the client, helped the students understand following: 1) value cannot defined by the single stakeholder associated with the project; it is a collaborative process and 2) the process is not sequential in nature with phased involvement of different specialities / functional areas but an iterative process with questioning of traditional notions and practices.

CHALLENGES

The step of evaluating cost data for each alternative indicates the transition of the design process within the realm of cost sensitive and driven nature of construction industry. The rationale behind plotting of cost against total advantage score is to relook at advantages offered by each design option and make a decision that ensures value maximization to the client. The availability of reliable data on cost of each option is very critical at this step. The students faced hurdles in seeking reliable cost information for few design alternatives owing to reasons like proprietary and confidential nature of cost, few or no projects using the proposed design alternatives, and long drawn process of collating cost information of different components to arrive at unit cost of design.

The reading material provided to students included papers on potential areas of application of CBA. However, there are no case studies as yet that explain the application of CBA in real life scenario and articles providing views of industry professionals that have used CBA method. The availability of these documents would have enriched the class discussion and instilled greater confidence in the minds of students about usability of CBA in cost conscious and non-collaborative construction process.

CONCLUSION

The CBA exercise discussed in this paper showed that students obtained enhanced understanding of collaboration and communication flow required between key stakeholders – client, contractor and designer during design process of construction project. These stakeholders principally strive to bring clarity on value to the client and its maximization. The students realized that the CBA offers structured approach for value

maximization at the design stage without diluting the much required collaboration and communication among stakeholders.

The lean philosophy has been gaining attention among construction professionals and academicians. The imparting of knowledge about lean construction along with classroom activities simulating real life environment of construction project for construction management students is important. In this context, this paper provides guidance on conducting CBA exercise in a classroom environment. There are a few limitation of this study. First, this study used the participant observation method, with the "instructor" roles of both participation and intervention. Therefore, there could be possibility of bias in observation and analysis. Secondly, the learnings reported in this study are influenced by various contextual variables like educational background of students, work experience, and prior knowledge of subject area.

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