SELECTION AND APPLICATION OF CHOOSING BY ADVANTAGES ON A CORPORATE CAMPUS PROJECT

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ABSTRACT

Architecture, engineering, and construction (AEC) teams need more efficient and effective decision-making methods, particularly in the pre-construction phase when decisions have the most significant impact on building performance. This paper discusses the selection and application of decision-making methods for the pre-construction phase of a lean corporate campus project. Findings are based on the project team's review of several value-based decision methods and final selection of the Choosing By Advantages (CBA) approach. CBA was implemented first using group preferences, then with simple additive weighting of individual preferences. In general, decision makers found that CBA enabled multi-disciplinary stakeholder participation and added value to decision-making for simple decision problems. However, decision makers also believed that CBA was inefficient and ineffective for more complex decision problems and did not adequately clarify decision rationale. Switching to individual preferences improved efficacy, efficiency, and value of information derived from the decision-making process, but clarity of rationale remained an issue due to the inherent complexity of decision problems and inconsistencies in factor selection between decisions. These observations suggest the need for future research concerning the design and implementation of appropriate tools for pre-construction decision-making on lean projects.

KEYWORDS

Choosing by advantages, decision making, pre-construction

INTRODUCTION

Over the course of a building project, architecture, engineering, and construction (AEC) consultants predict and evaluate the performance of many different design and construction options. The daily design-construction recommendations AEC consultants make to the client have significant impacts on building's sustainability throughout its life cycle. (Ugwu and Haupt 2007) With contractors and designers frequently working under strict budget and schedule constraints, AEC consultants need superior planning, design, and construction processes to meet client goals. Decision methods play an important role in successfully achieving these goals;

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however, there is a lack of consensus and understanding about appropriate decision processes in research and in practice.

This paper identifies desirable qualities of these decision methods and evaluates the appropriateness of current industry methods by discussing the selection of the Choosing By Advantages (CBA) decision method and its application during the pre-construction phase of a large-scale commercial building project. First, background is provided on the case study. The process and rationale of decision method selection on the project are then discussed and the implementation of CBA in the pre-construction phase is described. Finally, the chosen method is tested against several metrics adapted from the literature for selecting a decision-making approach. Based on the IPD team's feedback, two realizations of CBA are considered in terms of stakeholder participation, clarity of rationale, efficiency and effectiveness of process, and value of information delivered. The extent to which the applied decision methods enabled clearly communicated, high-quality alternatives is examined, and directions for future research are suggested.

BACKGROUND

One of the most active and important stages for decision-making is pre-construction. In this paper, pre-construction encompasses all of the phases in which changes to the design are minimal but design and construction details are still being finalized. This means that during pre-construction, decision makers have fewer, better-defined alternatives to consider and more information to accurately model and evaluate those alternatives as compared to early-stage design. However, as more details are determined, ability to alter project performance decreases and cost of design changes increases significantly. Typically, the impacts of pre-construction decisions have an immediate and often irreversible effect on project cost and schedule. While the client is the ultimate decision-maker, they generally lack the technical expertise to generate and evaluate different alternatives. Therefore, the client requires support from architects, engineers, and contractors, who must recommend a best alternative. Examples of pre-construction decisions include detailed system design (e.g. steel bracing configuration), trade partners (e.g. steel subcontractor), and construction information management systems (e.g. field document sharing). For each decision, only a handful of viable alternatives are likely.

The multidisciplinary nature of AEC decision-making and the engagement of multiple stakeholders often result in decision problems with multiple objectives. These decision problems call for a set of approaches referred to as multi-criteria decision-analysis (MCDA). MCDA methods structure and model the imprecise goals of multi-dimensional decision problems in terms of a set of individual decision criteria, where each criterion characterizes a single dimension of the problem to be evaluated. The general framework for most MCDA involves decomposing the decision problem into components, evaluating each component individually, and reassembling the components to provide overall insights and recommendations (Seppälä et al. 2002).

AEC professionals and researchers are investigating formal decision processes in practice, primarily for early-stage design and pre-construction. Although treatment of MCDA methods in construction decision-making literature is limited, a number of researchers have focused on developing decision support systems that use MCDA to select projects for investment (Dey 2006), choose project procurement methods (Kumaraswamy and Dissanayaka 2001; Anderson and Oyetunji 2003; Mahdi and Alreshaid 2005), and enhance early-stage design (Ugwu and Haupt 2007; Turskis et al. 2009; Flager et al. 2012). The majority of MCDA methods examined in the literature and implemented in practice are value-based. Value or utility theory approaches ask decision makers to develop a numerical score for each alternative and choose the one with the highest value. Examples include the analytic hierarchy process, multi-attribute utility theory, and simple multi-attribute rating techniques (Lahdelma et al. 2000).

For lean construction in particular, Macomber et al. (2006) propose a value-based method: Choosing By Advantages (CBA). Arroyo et al. (2012, 2013) explored applications of CBA in the construction industry and the characteristics that distinguish viable decision methods and concluded that CBA was superior to other value-based methods like AHP. In the AEC industry, CBA has been applied to decisions about green roof systems (Grant and Jones 2008), installation of viscous damping walls (Nguyen et al. 2009), and exterior wall assemblies (Arroyo et al. 2012, 2013). Several researchers have developed metrics for comparing and selecting decision processes. Hazelrigg (2002) considers whether a decision method: (1) allows a user to express preferences and uncertainties; (2) does not impose constraints or ordering, and; (3) self-consistently rank-orders alternatives. Given most complex AEC decisions are collaborative, Chachere and Haymaker (2011) propose metrics and a process for measuring the clarity of decision rationale, including teams involved in the decision, objectives defined, alternatives explored, impacts assessed, preferences stated, and values determined. Senescu and Haymaker (2013) recommend metrics and a process for measuring the efficiency and effectiveness of communicating process when creating rationale. Clevenger and Haymaker (2011) identify methods to measure and compare the challenges addressed, the methods used, and the exploration and guidance achieved.

CASE STUDY

A case study was undertaken as part of an Integrated Project Delivery (IPD) team on a major construction project. For two months during pre-construction, the author helped to facilitate the decision-making process. This involved interaction in several areas of the project, including life cycle cost assessment, milestone action planning and pull planning, and drafting sections of the project management plan. Each week, observations were conducted at team meetings to gain familiarity with the unique aspects of the IPD process.

The purpose of the project was to develop a new, sustainable corporate campus for an IT firm based in Silicon Valley. Design and construction was headed by a joint venture between two construction management firms with experience in highly sustainable buildings. The preliminary design consisted of several mid-rise buildings meant to house over 5,000 employees. The project had a budget of over $500 million – about $100/sq. ft. for interiors and $400/sq. ft. for core and shell. Observations began when the project was in the pre-construction phase. The team was in the process of applying for work permits, finalizing the concept and reaching 50% design, and making important decisions about trade partners (e.g. steel subcontractor), timing of major milestones (e.g. start date for grading), and project communications (e.g. platform for sharing architectural models),

The project owner and team sought clear communication and desired a rigorous decision-making process to ensure high-level cost, schedule, and sustainability goals would be met. The multi-objective, multi-disciplinary nature of decisions meant selecting an appropriate decision method was key. The team was concerned with identifying a suitable process for project-related decisions that significantly impacted cost or schedule and required supporting information from AEC professionals. Decisions included trade partner selection, jobsite technology adoption, and engineering systems comparisons.

SELECTION OF A DECISION METHOD

The two main approaches considered by the IPD team during pre-construction were the Weight, Rate, and Calculate method and the Choosing By Advantages (CBA) process. Both are value-based. A brief summary of each method is given below.

WEIGHT, RATE, AND CALCULATE (WRC)

Formally based on a multi-attribute objective function, WRC first defines and "weighs" the importance of objectives. The IPD team extended WRC to allow input from multiple stakeholders and competing weights on objectives. Following weighting, designers "rate" the performance of each alternative for each objective. WRC automatically "calculates" a value score for each alternative through a multiplication function of the importance weights of each objective and the performance of each option on each objective. The IPD team could view the value for each objective and from each stakeholder's point of view.

CHOOSING BY ADVANTAGES (CBA)

Many in the lean construction community have instituted the Choosing By Advantages (CBA) decision process (Macomber et al. 2006). Developed by James Suhr (1999), CBA's fundamental rule is that decisions must be based on the importance of advantages; decisions must not be based on attributes, advantages and disadvantages, or pros and cons. An attribute is a quality or consequence of one alternative. An advantage is a difference between the attributes of two alternatives. Since a disadvantage of one alternative is an advantage of another, when all of the advantages have been listed, all of the disadvantages have been listed. In CBA, it is impossible to assign valid numerical weights, ratings, or scores to factors, criteria, goals, etc. When a numerical weight is assigned, it must be assigned to an advantage. This is the importance of the advantage.

One of the most common CBA methods is the Tabular Method. In the Tabular Method, the decision-maker lists the advantages of each alternative in a special format and then decides the importance of each advantage. If there is no difference between the attributes of the alternatives, there is no advantage. If there is no advantage, there is no importance. Usually, if an advantage is small, its importance is small; if an advantage is large (and it matters), its importance is large. When deciding the importance of each advantage, the decision maker should first establish a scale of importance for the decision by choosing the paramount advantage and assigning it an importance score, then weighing all of the advantages on that scale. Deciding importance is subjective, but decisions about importance must be anchored to relevant facts. In the end, the decision-maker should choose the alternative with the greatest total importance of advantages. CBA also distinguishes between non-money and money decisions. "Money decisions" refer to any decision problems in which there is a difference in cost between alternatives. Different types of money decisions call for different money-decision-making methods. For setting priorities among non-exclusive proposals, CBA uses Importance/Cost ratios instead of typical Benefit/Cost ratios. To choose from mutually exclusive alternatives, CBA does not use Benefit/Cost ratios or Importance/Cost ratios.

SELECTION OF CBA

The IPD team did not apply formal rigor to the selection of decision method. Rather, the process of selecting a pre-construction decision-making approach on the case study was *ad hoc*. At first, each design and construction discipline was responsible for choosing a decision method. Each chose differently. The Architect used simplified CBA, creating a decision matrix that listed advantages of alternatives without specifying preferences. The Structural Engineer used WRC with preferences, but preference origin was unclear. The Mechanical Engineer listed attributes of alternatives without clarifying advantages or preference. Ultimately, the lack of common decision terminology and process caused confusion among decision makers and resulted in decisions that were not upheld.

The IPD team expressed clear interest in a unified approach and considered adopting WRC or CBA. On another construction project, one of the Joint Venture partners was experimenting with WRC. One person preferred WRC because he anticipated difficulties managing consensus in decision-making on a complex project involving multiple stakeholders with diverse interests and an owner with numerous, conflicting objectives. Others on the IPD team preferred to follow the growing trend in the lean community towards CBA. Eventually, the Project Managers decided to impose CBA for all design and construction disciplines. A workshop was arranged and spreadsheets were formatted and given to the project team to assist in modelling the decisions.

When the IPD team reconvened to discuss the decision models and make decisions, the Project Managers found that each team had made mistakes developing the CBA models. Design teams were asked to use the Tabular Method, but each team misapplied CBA using the provided spreadsheet. Thus, the Project Managers attempted to further standardize decision-making by using a web-based CBA platform intended to help improve team communication and to provide better documentation, additional support for the automated calculation of advantages, and better visualization tools for the results.

IMPLEMENTATION

For each pre-construction decision, the team lead from the appropriate discipline was responsible for creating a new decision in the web-based tool and sharing it with the relevant decision makers and designers. He was also responsible for generating a set of goals, including units of measurement for each goal, any relevant constraints, and each alternative under consideration. Following CBA, cost was not included in the list of goals.

After establishing the list of decision objectives, the discipline lead, alone or with assistance from other team members, described the attributes of each alternative by goal category. In each goal category, the lead or the team collectively identified the alternative with the worst or least desirable attribute and described the advantages of every other alternative's attribute relative to the worst attribute. Once all advantages were described, decision makers assigned an importance score ranging from 1 (Lowest Importance) to 100 (Highest Importance) to each advantage. In most decisions, the decision makers established one set of importance scores on which they all agreed. For the field document management decision, the CBA methodology was extended to allow the decision makers to assign importance scores individually through their online accounts.

If the decision makers believed that cost differences between the alternatives were irrelevant, the alternative with the highest Total Importance Score was recommended. Conversely, if the decision makers believed that cost differences were relevant, the discipline lead determined the ratio of Total Importance Score to Cost, and the alternative with the highest ratio was recommended. The only decision for which cost was considered was steel trade partner selection because the cost difference between the bids (15% of the bid amount) was deemed significant. The lead incorporated the impact assessment matrix and any other outputs he thought necessary into the recommendation. Figure 1 shows the user interface for impact assessment in the online decision platform.

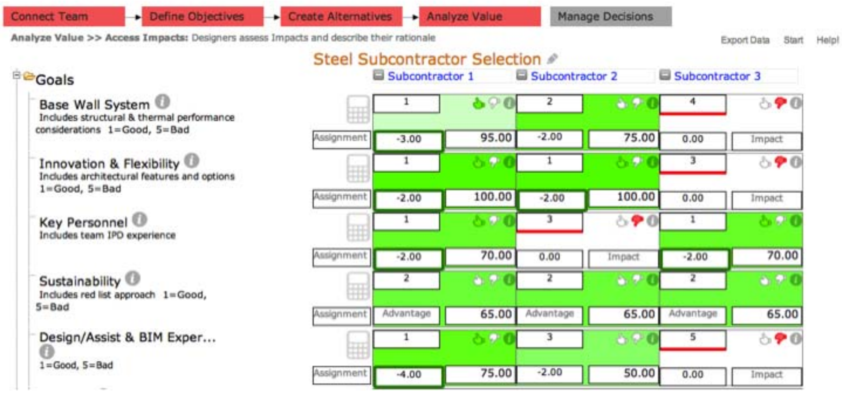

Figure 1: Impact Assessment Matrix for CBA in the Online Decision Support Platform

DISCUSSION

For this work, the quality of group CBA and individual CBA as decision-making processes was assessed based on participant observations and feedback from the IPD team. Each approach was evaluated on five criteria: stakeholder participation, clarity of rationale, efficiency of process, effectiveness of process, and value of information.

GROUP IMPLEMENTATION OF CHOOSING BY ADVANTAGES

Under the evaluation criteria, group CBA has a number of important strengths. The first iteration of CBA brought multiple, multi-disciplinary stakeholders to the table to discuss the decision problem. While the lead facilitator determined initial participation, those involved could recommend or invite additional stakeholders to participate in the decision-making if necessary. Since group CBA was run through meetings in person, questions about goals, attributes, and alternatives could be quickly resolved and the IPD team's rationale clarified. The data-supported approach and quantitative comparison of alternatives made CBA more credible in the eyes of the owner and the IPD team, and the flexibility in naming the decision factors allowed for a multi-disciplinary, multi-objective process that reflected the owner's goals and the changing priorities on the project.

As a practical decision-making method, group CBA has several weaknesses. Often, a coalition of stakeholders or a vocal minority would dominate the discussion, influencing the group assignment of importance scores. Many members of the IPD team felt that the importance scores could be easily manipulated, especially in categories like sustainability and innovation, which were more ambiguously defined. The IPD team found that group CBA was not well designed for more complex decisions with three or more alternatives as decision-making rationale became less obvious. This was also true for decisions where cost was important because the money methods were not intuitive and the IPD team thought the qualitative benefits were exaggerated as a consequence. While the exercise of listing criteria was important to decision makers as a "thinking tool," there was no systematic way to incorporate sustainability or to consider trade-offs across design disciplines or decisions. Decision frameworks were designed to find the optimal solution for a particular decision without considering the broader network of decisions, which were all linked through the strict budget constraints for the project. Criteria and quality of data were inconsistent among decisions, depending heavily on the lead, which meant that important sustainability objectives were often treated differently or overlooked when relevant. Moreover, the team required a better way to incorporate cost to make sense of the connections between cost and importance. Cost is deeply tied to all decision-making; the estimators (on-site and off-site) were nearly always included in the conversation.

The flexibility of stakeholder participation and factor identification and, more notably, the difficulty of determining importance scores collaboratively, greatly hindered process efficiency. Decision leads spent significant time setting up the process. Due to concerns that results were biased or incomplete, additional time was needed to verify information or even redo the group CBA analysis. On several occasions, decision makers asked for more data from the different disciplines or from third parties in the case of trade partner selection. Such repeated requests were a nuisance for designers and meant decisions were regularly delayed. Although group CBA allowed AEC consultants and clients to share information in real time and collaborate more effectively, participants felt time spent in meetings trying to reach consensus on importance scores was unproductive. Furthermore, group CBA did not provide a clear way for decision makers to deal with uncertainty, a key part of decision analysis (though not formally applied on most projects).

INDIVIDUAL IMPLEMENTATION OF CHOOSING BY ADVANTAGES

The final application of CBA addressed several concerns associated with group CBA. Stakeholders could express individual preferences, using their domain expertise to assign importance scores independently. With individual CBA, the IPD team expressed greater acceptance of the results and felt that they more closely reflected the true differences between alternatives. Process efficacy improved as less iteration was needed to reach a final decision. Soliciting stakeholder input independently also meant less time devoted to reaching group consensus on importance scores in meetings.

However, as decision problems grew more complex, individual CBA became harder to work with effectively. Part of this difficulty was due to users' lack of comfort with the CBA process; part was due to the design of the online tool. Since emphasis was not on group consensus, individuals were more likely to diverge in their understanding of the alternatives and decision rationale. Averaging importance scores meant that the final decision depended on CBA participants. Consequently, appropriate stakeholder representation became a key issue for decision leads. Again, cost analysis and money methods remained absent from the online tool, and uncertainty was excluded from the process. Table 1 summarizes the performance of group and individual CBA by metric.

Table 2: Evaluation of Group and Individual Choosing By Advantages

	Group Choosing By Advantages	**Individual Choosing By Advantages**
Stakeholder Participation	• Determined by lead facilitator with input from other stakeholders • Dominated by vocal minorities • In-person interactions	• Determined by lead facilitator with less input from other stakeholders • No group discussions • Virtual interactions
Clarity of Rationale	• Objectives set by lead facilitator on a decision-specific basis, often supplemented by other stakeholders • Objectives clarified with group • No simple way to account for cost • Stakeholder priorities hidden	• Objectives set by lead facilitator on a decision-specific basis, occasionally supplemented by other stakeholders • Objectives clarified with individuals • No simple way to account for cost • Stakeholder priorities hidden
Efficiency of Process	• Repeated requests for information • Long hours spent in meetings to reach consensus on scores	• Repeated requests for information • Less time spent in meetings since preferences were individual
Effectiveness of Process	• Concerns about coalitions of stakeholders (e.g. vocal minorities) manipulating importance scores • Rejection and skepticism of some outcomes required more iterations	• Concerns about representation of disciplines among stakeholders affecting average importance scores • Greater trust in quality of outcomes meant fewer iterations
Value of Information	• Represented group preferences • Quantitative aspect made outcome more legitimate to stakeholders • Multiple owner objectives could be considered in the analysis • Did not account for uncertainty	• Represented individual preferences • Quantitative aspect made outcome more legitimate to stakeholders • Multiple owner objectives could be considered in the analysis • Did not account for uncertainty

CONCLUSION

This paper describes the investigation and adoption of decision methods on a corporate campus project. After testing two value-based approaches (Weight, Rate, and Calculate and Choosing By Advantages) within design disciplines, the IPD team adopted group CBA and later introduced individual CBA, both supported by an online tool. The two versions of CBA were evaluated based on five quality metrics related to process quality and suitability for pre-construction decisions. Although group CBA allowed stakeholders to participate more actively in decision formulation and reach a shared understanding of objectives, attributes, and importance scores in decision evaluation, group CBA required more iteration through the decision process to reach a solution and, even then, was not always satisfactory. Individual CBA was more effective and efficient than group CBA and produced more valuable information for decision makers. In both cases, clarity of rationale was an issue due to the complexity of multi-objective, multi-disciplinary decision problems and inconsistencies in factor selection between decisions. Frustrations were particularly high on the IPD team regarding the ease with which CBA weighting schemes could be manipulated to achieve a desired outcome. Further research will be conducted to validate the criteria for selecting an appropriate decision method given a specific decision problem. Presently, workshops are being organized to assess the value of implementing formal decision processes and compare the quality of different multi-attribute decision analysis methods from a user satisfaction perspective. This investigation will move beyond the simple value-based processes addressed in this paper to include outranking methods and single value function methods. The effects of using group versus individual preferences, as well as decision facilitator versus owner preferences, will also be examined.

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