USING ‘CHOOSING BY ADVANTAGES’ TO SELECT CEILING TILE FROM A GLOBAL SUSTAINABLE PERSPECTIVE

Paz Arroyo[1], Iris D. Tommelein[2] and Glenn Ballard[3]

ABSTRACT

Decisions in the architecture, engineering and construction industry need to be supported by decision-making methods. Choosing By Advantages (CBA) offers methods that support the creation of transparency and collaborative environments in which to make decisions. This paper provides an example of how CBA can be of support when choosing materials, in this case ceiling tiles, in a commercial-building interior-design project considering global supply-chain issues. The results show that CBA is helpful in integrating multiple stakeholders’ perspectives, in identifying relevant sustainability factors based on the decision context, in making transparent trade-offs between advantages of the alternatives, in providing documentation for the decision rationale, and in separating “value” and cost. Materials that are judged to be more sustainable than others in one geographic location, may be judged less sustainable than others elsewhere.

KEYWORDS

Decision-making, Choosing By Advantages, CBA, Sustainability, Design Management, Supply Chain Management.

INTRODUCTION

Decision-making methods can influence decision outcomes. According to Suhr (1999), decision-making methods influence people’s decisions, decisions trigger actions, and finally actions cause outcomes; consequently, if outcomes matter, then the decision-making methods also matter. Here we focus on deciding on the selection of a material. Material selection for a commercial building’s interior design affects outcomes in terms of the building’s lifecycle, including environmental-, social-, and economic impacts. Specifically, it will affect the users’ indoor environmental quality, involving light, acoustics, air quality and thermal comfort. In addition, it affects the environment. Finally, it affects the economics of the project, given their initial cost, maintenance cost, life expectance, replacement cost, construction sequence, procurement lead time, etc. Different from traditional buildings, sustainable projects will have more stakeholders involved and more factors when selecting materials.

---

[1] Graduate Student Researcher, Engrg. and Project. Mgmt. Program, Civil and Envir. Engrg. Dept., Univ. of California, Berkeley, CA 94720-1712, USA, Phone +1 (510) 386-3156; parroyo@berkeley.edu

[2] Professor, Civil and Envir. Engrg. Dept., and Director of the Project Production Systems Laboratory (p2sl.berkeley.edu), Univ. of California, Berkeley, CA 94720-1712, USA, Phone +1 (510) 643-8678, tommelein@ce.berkeley.edu

[3] Research Director, Project Production Systems Laboratory (p2sl.berkeley.edu), Civil and Envir. Engrg. Dept., Univ. of California, Berkeley, CA 94720-1712, USA, ballard@ce.berkeley.edu

Globalization together with the rise of multinational companies have created demand for commercial buildings that require a similar look-and-feel, if not an identical design, in order to create a strong corporate identity and an effective work environment. This demand results in more complex supply chain management.

In this paper we apply the Tabular Method of Choosing By Advantages (CBA) to overcome the challenge of managing information when selecting sustainable materials while accounting for the perspectives of multiple stakeholders in global corporate offices. This paper presents a case study in which designers chose ceiling tiles for a global commercial-building interior-design project.

METHODOLOGY

This research is based on case-study methodology as recommended by Yin (1994). It understands case study as “an empirical inquiry that investigates a contemporary phenomenon within real-life context, especially when the boundaries between the phenomenon and context are not clearly evident” (Yin 1994). This definition is aligned with the scope of this research, especially because sustainability decisions in building design are tightly linked to the problem context.

CHOOSING BY ADVANTAGES (CBA)

CBA is a decision-making system that supports sound decision-making using comparisons among advantages of alternatives. Suhr developed it while working in the U.S. Forest Service. Examples of CBA applications in the AEC industry can be found in Parrish and Tommelein (2009), Grant (2007), Nguyen et al. (2009), and Arroyo et al. (2012a and b). Table 1 presents CBA definitions adapted from Suhr (1999).

Table 1: CBA Definitions.

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 alternatives have been evaluated based on factors and criteria.
Criterion	A decision rule, or a guideline. A ‘must’ criterion represents conditions 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 a beneficial difference between the attributes of two alternatives.

The CBA system has four principles: (1) decision makers must learn and skilfully use sound methods of decision making; (2) decisions must be based on the importance of the advantage; (3) decisions must be anchored to the relevant facts; (4) different types of decisions call for different sound methods of decision making.

In CBA, decisions are based solely on the advantages (Principle 2) (rather than advantages and disadvantages) thereby avoiding double counting. Once the advantages are found, stakeholders need to assess the importance of these advantages by making comparisons among them. The weighting process should be specifically on the importance of these advantages, not generally on criteria, factors, or other types of data (Suhr 1999, p. 80). The CBA Tabular Method for moderately complex decisions has five phases: (1) the Stage-Setting Phase, (2) the Innovation Phase, (3) the Decision-making Phase, (4) the Reconsideration Phase, and (5) the Implementation Phase. The focus of this paper is on phase (3). Here we describe the decision-making process in 7 steps (Figure 1). However, phase (3) originally considers only steps 4 to 5 in Suhr’s book (1999). The previous steps are part of the innovation phase.

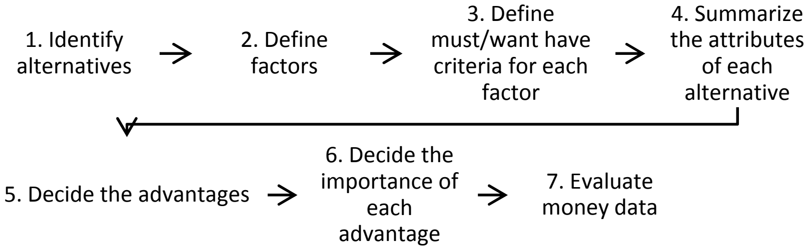


Figure 1: CBA Steps

In step 1, stakeholders choose alternatives likely to yield important advantages over other alternatives. In step 2, they define factors with the purpose of differentiating between alternatives. In step 3, stakeholders agree on the criteria within each factor. Criteria will be used to evaluate attributes of alternatives. A criterion can be either a desirable (want) or a mandatory (must) decision rule. Alternatives that do not comply with a must criterion are not considered in the following steps. In step 4, stakeholders summarize the attributes of each alternative. In step 5, they identify the least preferred attribute for each criterion, and then decide on the advantage of each alternative’s attribute relative to that least-preferred one. In step 6, they decide on the importance of each advantage (IofA). Stakeholders need to explicitly state their preferences for these IofAs. First they have to select the paramount advantage, which is the most important advantage among all. They use the paramount advantage to assign an IofA scale, with the IofA of any least-preferred attribute always getting a zero relative to itself (the paramount advantage was assigned 100 IofAs in Table 3). The choice of scale does not distort the evaluation, Stakeholders then use this scale to weigh other advantages. The IofA for each alternative is summed. In step 7, finally, stakeholders evaluate cost data and select from the alternatives.

This process is highly collaborative and the design team should be involved at every stage. Once an alternative has been chosen, the group will take time to reconsider their decision (Phase 4) as a whole, incorporating a holistic analysis into the sustainability decision-making process. This phase raises the following questions: Are any additional alternatives that to be considered? Does the importance of advantages accurately represent the viewpoint of the stakeholders?

APPLICATION EXAMPLE: CHOOSING CEILING TILES

This case study applied CBA to a Design-Bid-Build (DBB) project, in which the client, a Global Information Technology company wanted to renovate their offices in many locations around the world, while seeking LEED (Leadership in Energy and Environmental Design) gold certification. A large architectural firm needed to rapidly and consistently design many global locations. The San Francisco location was designed first and used as a prototype for the other locations around the world. For this study, the design team analyzed San Francisco, New York, Sydney, Dublin, and Tokyo because these were thought to be representative of strategic locations in the world. The main design choices in terms of cost for those interior design projects were the carpet, ceiling tile, and furniture. The researcher (the first author on this paper) analyzed the availability of specific products for different locations and conducted a deeper analysis on ceiling tile alternatives considering one manufacturer.

CASE STUDY PROTOCOL

The case study protocol describes the steps that the researcher followed for applying CBA in this project. (1) The researcher facilitated the decision-making process, so she had to master the CBA system. She read relevant literature and attended a 2 day CBA workshop (Koga 2012). (2) The researcher obtained access to the project information and was aware of the background of the decision. In this case, access was enabled through an internship. (3) The researcher had to understand the requirements for product selection (in this case ceiling tile), in terms of lead times, availability, LEED credits, aesthetics, installation procedures, etc. This information was obtained by direct communication with the design team. (4) The researcher was able to identify competitive alternatives and gather relevant information from manufacturers and designers, including EPD (Environmental Product Declaration). From there, relevant factors, criteria for selection and attributes of the alternatives were articulated. (5) The researcher prepared a training session for the design team that covered the following points: importance of the decision-making process, description of CBA methodology, an example of a CBA application, discussion and questions. (6) The researcher discussed the alternatives to analyze with the design team. In addition, the researcher presented the relevant information for the decision-making process, the process for obtaining the information, and assumptions behind the data presented. (7) The researcher led a decision session, which was videotaped, so the interaction between the design team could be analyzed later. The design team was asked about the procedure, what worked well and what did not. (8) The researcher documented the decision-making process and wrote recommendations for choosing ceiling tiles. This document was sent to the design team to obtain feedback. (9) The process and the results of the decision were analyzed in a post-decision meeting to gather further insights about the method, barriers for implementation and future applications in the company. (10) Finally, the case study report was sent to the design team for feedback. The design team recognizes the benefits of using CBA, though they expressed that they may not always have the time to analyze decisions at this level of detail.

STEP BY STEP CBA APPLICATION

Step 1: Identify Alternatives. For this case study, the design team looked at just one manufacturer (Armstrong), but it could have just as easily compared products from different manufacturers. The alternatives considered are shown in Table 2. Aesthetically all options look the same and all can be installed with the same system (Tegular). All ceiling tiles are available in 2’x2’ and 3’x4’ sizes.

Table 2: Ceiling tiles alternatives

Alternative	Optima	Ultima	Optima PB	Optra
Material	Fiberglass	Mineral fiber	Fiberglass with plant based binder	Biosoluble glass wool
Manufactured in	Hilliard, OH	Pensacola, FL. Marietta, PA. Munster, Germany. Shanghai, China.	Hilliard, OH	Shanghai, China.

Step 2: Define Factors. Stakeholders need to identify factors that will help differentiate between alternatives. It is not about which factor is most important. Factors that have an impact on the decision will change depending on the attributes of the alternatives, and the importances assigned to advantages. Many factors were not considered in the decision-making process since the alternatives have similar attributes for those factors (e.g., all alternatives have the same fire resistance rating). In addition, some factors that had the same purpose were merged together. For example recycled content, energy use, locally-sourced material, were all contained in the Global Warming Potential factor, which represents a more holistic view of the environmental impacts.

Step 3: Define the "must"/"want to have" criteria for each factor. For each factor, stakeholders need to agree on criteria on which to base their judgement of alternatives. A criterion can be a "must have" or a "want to have". Some attributes have a standard evaluation in which case it is easy to establish a criterion (e.g., weight, insulation value, guaranty period, etc.). In other cases, stakeholders need to describe what they want (e.g., Anti-microbial barrier). We next explain what stakeholders understood by each factor and their criteria for evaluation. Factors and criteria considered in this decision are summarized in Table 3 (first column).

Factor 1 Acoustics: In this particular case, stakeholders decided that the Noise Reduction Coefficient (NRC) would be important due to the high percentage of open spaces. NRC is a measure of the average percentage of noise that a material absorbs in the mid-frequency range. Therefore, the criterion for this factor is: A higher NRC value is better; the minimum acceptable NRC value is 0.7 for open spaces.

Factor 2 Anti-microbial barrier: This factor accounts for the ceiling tile's resistance against the growth of mold and mildew. For fiberglass tiles this is not an issue because it does not contain organic compounds. However, for mineral fiber tiles an antimicrobial treatment on the face and back is required to obtain acceptable performance. The mold and mildew resistance can be tested using the ASTM D 3273 method. The criterion for this factor is: More microbial resistance is better.

Factor 3 Durability: In this instance we will consider impact and scratch resistance. Using the falling ball impact test (procedure similar to ASTM D 1037), which accounts for surface impact, and the Hess Rake Test, which accounts for scratch resistance. In this case, ceiling tiles will be removed frequently for plenum access. Therefore, the stakeholders agreed that surface scratch resistance is desirable. The criterion for this factor is: More resistant to scratches and impact is better.

Factor 4 Weight: Here the stakeholders decided that a lighter material would be better, because it would be easier to install than a heavier material. The criterion for this factor is: Lighter is better.

Factor 5 Insulation Value: This accounts for a material resistance to heat transfer. It is measured using the R-Value, in which a higher value indicates a higher thermal resistance. The criterion for this factor is: Higher R-value is better.

Factor 6 VOC (Formaldehyde): This factor accounts for the indoor air quality that will result from the selection of ceiling tile. Stakeholders agree that low VOC materials are desirable. Here specifically this means materials without added formaldehyde. Exposure to formaldehyde is a significant consideration for human health. Stakeholders agreed that materials must comply with California Department of Health Services (CHPS) Standard Practice for the testing of VOC Emissions and qualify for 'Low-Emitting.' The criterion for this factor is: No added formaldehyde is better.

Factor 7 Guaranty: Stakeholders defined that having more years of guarantee is desirable. However, this depends on how long the client plans to stay in the same office building. The criterion for this factor is: More years of guarantee is better.

Factor 8 Global Warming Potential (GWP): This factor accounts for the environmental impact of the materials. Here stakeholders decided to use the environmental product declaration (EPD) provided by the manufacturer. EPDs account for CO_2(e) emissions using a life cycle analysis (LCA)., Encompassing raw material production, transport of raw materials to production facility, manufacturing of ceiling panels, packaging, transportation to job site (manufacture data assumes 500 miles of transportation), use phase, and end of life including disposal or recycling. The criterion for this factor is: Less CO_2(e) emissions is better.

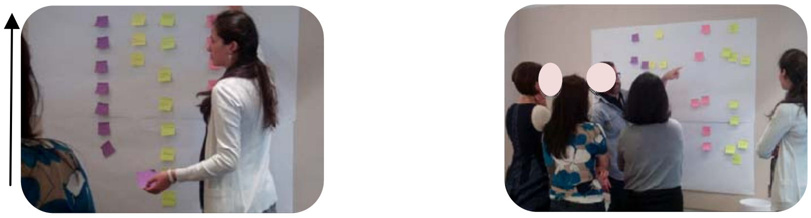
Step 4: Summarize the attributes of each alternative. The attributes of each alternative can be found in the manufacturer's technical documents and the EPD data. Since most sites are not located within 500 miles from the nearest site of tile manufacturing, the researcher adjusted the transportation to job site portion of the LCA, according to estimated distances from manufacture plant to site. The analysis also considered the transportation mode (truck or vessel) according to manufacturer information. The attributes of factor WGP will vary according to the project site, transportation mode and manufacture plant location. Table 3 summarizes the attributes of the alternatives. The least preferred attributes are underlined and will be used as comparison points to describe advantages.

Table 3: CBA steps 1-6.

Factor & Criterion	Optima (Fiberglass)		Ultima (Mineral Fiber)		Optima Plant Based (Fiberglass)		Optra (Fiberglass)	
1. Acoustics NRC	Att: 0.9		Att.: 0.7		Att.: 0.95		Att: 0.9	
Crit.: Higher is better	Adv.: 0.2 Higher noise resistance	Imp.: 100	Adv.:	Imp.: 0	*Adv.: 0.25 Higher noise resistance*	Imp.: 100	Adv.: 0.2 Higher noise resistance	Imp.: 100
2. Anti-microbial	Att: Inherent		Att.: It has BioBlock+		Att: Inherent		Att: Inherent	
Crit.: Higher is better	*Adv.: Better Anti-Microbial*	Imp.: 15	Adv.:	Imp.: 0	*Adv.: Better Anti-Microbial*	Imp.: 15	*Adv.: Better Anti-Microbial*	Imp.: 15
3. Durability	Att.: Scratch resistance Impact resistance		Att.: Scratch resistance Impact resistance		Att.: Scratch resistance Impact resistance		Att.: No Scratch resistance No Impact resistance	
Crit.: Higher is better	Adv.: *More resistant to Scratches and impact*	Imp.: 25	Adv.: *More resistant to Scratches and impact*	Imp.: 25	Adv.: *More resistant to Scratches and impact*	Imp.: 25	Adv.:	Imp.: 0
4. Weight	Att.: 0.55 (lbs/sqft)		Att.: 1.14 (lbs/sqft)		Att.: 0.55 (lbs/sqft)		Att.: 0.48 (lbs/sqft)	
Criterion: Lighter is better	Adv.: 0.59 (lbs/sqtf) lighter	Imp.: 50	Adv.:	Imp.: 0	Adv.: 0.59 (lbs/sqtf) lighter	Imp.: 50	Adv.: *0.66 (lbs/sqtf) lighter*	Imp.: 50
5.Insulation Value	Att.: R Factor 4.0 BTU		Att.: R Factor 2.2 BTU		Att.: R Factor 4.0 BTU		Att.: R Factor 3.0 BTU	
Crit.: Higher is better	Adv.: *1.8 BTU higher*	Imp.: 45	Adv.:	Imp.: 0	Adv.: *1.8 BTU higher*	Imp.: 45	Adv.: 0.8 BTU higher	Imp.: 40
6. VOC Formaldehyde	Att: Low Formaldehyde - less than 13.5 ppb		Att: Free of Formaldehyde		Att: Free of Formaldehyde		Att: Low Formaldehyde - less than 13.5 ppb	
Crit.: Lower is better	Adv.:	Imp.:0	Adv.: *Free of Form.*	Imp.: 90	Adv.: *Free of Form.*	Imp.: 90	Adv.:	Imp.:
7. Guaranty	Att.: 30 Year Guarantee		Att.: 30 Year Guarantee		Att.: 30 Year Guarantee		Att.:15 Year Guarantee	
Crit.: Longer is better	Adv.: *15 More Years of Guarantee*	Imp.: 90	Adv.: *15 More Years of Guarantee*	Imp.: 90	Adv.: *15 More Years of Guarantee*	Imp.: 90	Adv.:	Imp.: 0
8. CO_2 Emission SF	Att.: 275 t CO_2eq		Att.: 392 t CO_2eq		Att.: 275 t CO_2eq		This alternative is not available in SF	
Crit.: Lower CO_2 emission is better	Adv.:*7 t CO_2 less*	Imp.: 30	Adv.:	Imp.: 0	Adv.:*7 t CO_2 less*	Imp.: 30		
8. CO_2 Emission NY	Att.: 44 t CO_2eq		Att.: 58 t CO_2eq		Att.: 44 t CO_2eq		This alternative is not available in NY	
Crit.: Lower is better	Adv.:*14 t CO_2 less*	Imp.: 35	Adv.:	Imp.:	Adv.:*14 t CO_2 less*	Imp.: 35		
8. CO_2 Emission Tokyo	Att.: 54 t CO_2eq		Att.: 70 t CO_2eq		Att.: 54 t CO_2eq		Att.: 56 t CO_2eq	
Crit.: Lower is better	Adv.:*15 t CO_2 less*	Imp.:35	Adv.:	Imp.:	Adv.:*15 t CO_2 less*	Imp.:35	Adv.:14 t CO_2eq less	Imp.:35
8. CO_2 Emiss. Sydney	Att.: 22 t CO_2eq		Att.: 30 t CO_2eq		Att.: 22 t CO_2eq		Att.: 23 t CO_2eq	
Crit.: Lower is better	Adv.:*8 t CO_2 less*	Imp.: 30	Adv.:	Imp.:	Adv.:*8 t CO_2 less*	Imp.: 30	Adv.: t CO_2eq less	Imp.: 30
8. CO_2 Emiss. Dublin	Att.: 61 t CO_2eq		Att.: 80 t CO_2eq		Att.: 61 t CO_2eq		Att.: 68 t CO_2eq	
Crit.: Lower is better	Adv.:19 *t CO_2 less*	Imp.: 35	Adv.:	Imp.:	Adv.:19 *t CO_2 less*	Imp.: 35	Adv.:12 t CO_2eq less	Imp.: 35
Total IofA SF		355		205		445		
Total IofANY		360		205		450		
Total IofA Tokyo		360		205		450		240
Total IofA Sydney		355		205		445		235
Total IofA Dublin		360		205		450		240

Step 5: Decide the advantages of each alternative. Once the attributes are summarized, the criteria are applied to identify the advantages. In this case, the advantages were easily found. Table 3 presents the advantages of the GWP factor for each location, considering the amount of ceiling tiles required in each office. Note that for each factor there will be always at least one alternative that does not have an advantage because it is the one that has the least preferred attribute or characteristic in that criterion. The most important advantage for each factor is shown in italics.

Step 6: Decide the importance of each advantage. This part of the process is collaborative and decisions are reached through discussion within the design team. The client vision should be considered in every trade-off that is made. An easy way of assigning IofAs to advantages is to write them in post-it notes, then draw a scale from 0 to 100 (or any other convenient scale, as defined by the paramount advantage), and finally place the notes according to their importance relative to others (Figure 3). A more detailed procedure is to first identify the most important advantage for each criterion (in italics in Table 3) and then choose the paramount advantage. In this case stakeholders decided that the 2.5 IofA higher value in the NRC rating (0.95 of Optima PB – 0.7 Ultima) was the paramount advantage, because it will make an important difference in the user experience. Therefore, stakeholders assigned 100 IofAs to this paramount advantage. Next, assign an importance score to the most important advantages for each criterion (the ones in italics in Table 3) by comparing them with the paramount advantage. In this case the advantage 'free of added formaldehyde' was the second most important advantage (90 IofAs), with 15 years of guarantee (90 IofAs). Finally, assign importance points to the other advantages. Once all advantages have been assigned IofAs, the total importance of each alternative is computed. In this way it is easy to compare which alternative provides a higher Importance of Advantages (IoA) score (Table 3).



List the advantages of each alternative

Discuss the importance of each advantage

Figure 3: Step 6, deciding collaboratively on the importance of the advantages

Step 7: Evaluate cost data. To evaluate cost data, the design team plots the total IoA score for each alternative against the local cost (Figures 4). In this example, choosing Ultima for Japan, Sydney or Dublin does not make sense since Optra costs less and it has advantages that are more important. The decision, then, is whether or not to spend more money on an alternative that provides more advantages. This depends on the client and other investment choices they face. In the short term, Optra is a cheaper option than Optima or Optima PB. However, stakeholders will be losing some advantages if they select Optra over Optima PB, including using a product with vs. without formaldehyde, getting 15 vs. 30 years of guarantee and no vs. some scratch and impact resistance. But stakeholders will be winning other advantages such as using a product that weight 0.48 (lbs/sqft) vs. 0.55 (lbs/sqft).

For New York and San Francisco Optra is unavailable in the market, so the alternatives are reduced. Recommending the selection of Optima vs. Optima PB is not difficult because Optima PB does not have formaldehyde and costs only $0.25 more per sf. However, the decision of using Ultima vs. Optima PB will depend on the budget of the project ($0.25 more per sf may not be available). Finally, using CBA, stakeholders are able to provide clear rationale for their decisions. In addition, they can use their CBA tables and money-vs-IoA plots to learn from project to project. The manufacturer also will learn about what tradeoffs designers make when selecting products.

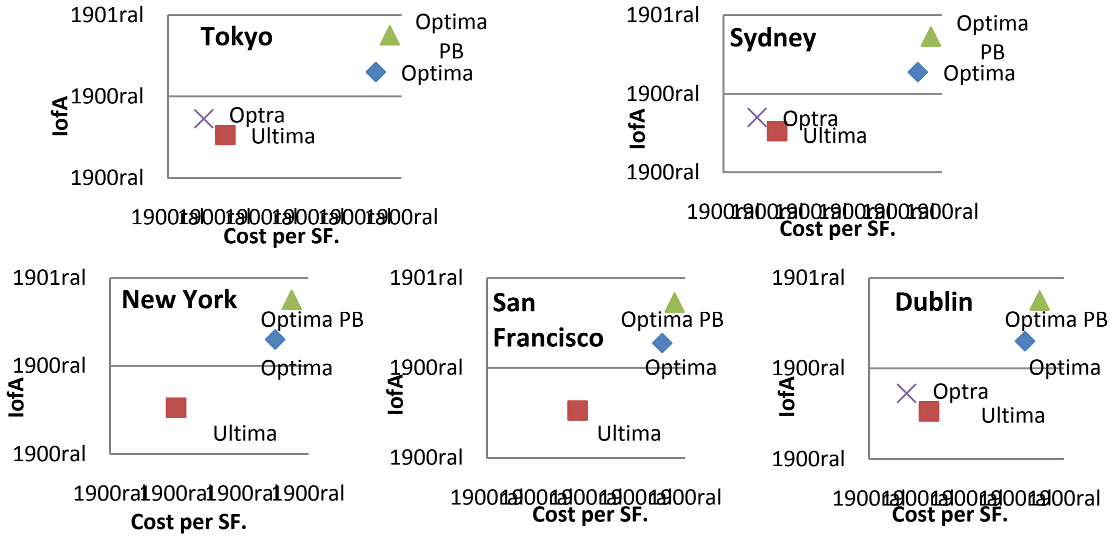


Figure 4: CBA Results for the different locations.

CONCLUSIONS

The conclusions of this case study that may be generalized are: (1) CBA was helpful in integrating multiple stakeholders' perspectives. (2) CBA was helpful in the identification of relevant sustainability factors applicable for the decision context. (3) CBA was helpful in identifying advantages that were relevant for making transparent and conflict-free trade-offs between alternatives. (4) CBA was helpful in providing documentation for the decision-making rationale. (5) CBA was helpful in separating the "value" of the alternatives from the cost of alternatives, making it easier to trade off "value" vs. cost. (6) CBA was helpful in organizing factors that had different attributes depending on location (Global Warming Potential factor). (7) CBA structure made easy to incorporate the supply chain portion of the decision.

Barriers that were identified in applying CBA for choosing a sustainable alternative were: (1) Intensive time use in data collection. (2) Time for analysis exceeds the expectation of the team for choosing materials in this type of project. An extensive time analysis may be appropriate for other projects in which the owner demands a rationale for the decision. (3) Not all manufactures have an EPD. Data collection can be challenging, especially for comparing products from the environmental perspective. (4) It was not possible to get all relevant stakeholders together in one room at the moment of the decision. In this case, an owner's representative, final user, and contractor were not present. Therefore, architects and interior designers assigned the importance of advantages representing the client values, as they understood them.

Finally, if designers use CBA to select materials, it would be easier for them to select more 'sustainable' materials according to their values, when compared to making decisions using less structured methods. At the same time, this information can be transformed into market feedback, especially for manufacturers, so their new product development is aligned with what the industry is asking for, and in a long term, produce more sustainable materials.

ACKNOWLEDGMENTS

This paper was supported in part by gifts made to the Project Production Systems Laboratory (P2SL). In addition, P. Arroyo is supported by a CONICYT Ph.D. fellowship from the Chilean government. We would like to thank Erin Cubbison, Kirsten Ritchie and designers from Gensler San Francisco for their support in this case study. Any opinions, findings, conclusions, or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of P2SL, CONICYT, or Gensler.

REFERENCES

Armstrong (2012) "Optima Ceiling Panels, High Performance Fiberglass, Environmental Product Declaration" Available at: http://www.armstrong.com/common/c2002/content/files/72527.pdf Accessed 3/19/2013.

Arroyo, P., Tommelein, I., and Ballard, G. (2012a). "Deciding a Sustainable Alternative by 'Choosing By Advantages' in the AEC Industry". Proc. 20th Ann. Conf. Int'l. Group for Lean Construction (IGLC), San Diego, CA.

Arroyo, P., Tommelein, I., and Ballard, G. (2012b). "Comparing Multi-Criteria Decision-Making Methods to Select Sustainable Alternatives in the AEC Industry". 2nd International Conference for Sustainable Design, Engineering and Construction (ICSDEC), Fort Worth, TX.

Grant, E. (2007). *A Decision-Making Framework for Vegetated Roofing System Selection.* PhD Dissertation, Architecture and Design Research, Virginia Polytechnic Institute and State University, Blacksburg, VA, 300 pp.

Koga, J. (2012) "Choosing By Advantages Sound Decisionmaking." CBA workshop Module 1 and Module 2, 6-7 June, San Francisco, CA.

Nguyen, H. V., Lostuvali, B., Tommelein I. D. (2009). "Decision Analysis Using Virtual First-Run Study of a Viscous Damping Wall System." *Proc. 17th Annual Conf. Int'l. Group for Lean Constr.* (IGLC 17), 15-17 July, Taipei, Taiwan, 371-382.

Parrish, K., Tommelein, I. D. (2009). "Making design decisions using Choosing By Advantages." *Proc. 17th Annual Conference of the International Group for Lean Construction* (IGLC 17), 15-17 July, Taipei, Taiwan, 501-510.

Suhr, J. (1999). *The Choosing By Advantages Decisionmaking System*. Quorum, Westport, CT, 293 pp.

Yin, R. K. (1994). *Case Study Research: Design and Methods*. Sage Publications, Inc., Thousand Oaks, CA, 171 pp.