Analysis of Decision Making Process in Construction Industry through the Construction Decision Making Inventory (CDMI)

Tulio Sulbaran, tulio.sulbaran@usm.edu
Professor, University of Southern Mississippi, Hattiesburg, Mississippi, USA

Mazdak Nik-Bakht, mazdak.nikbakht@concordia.ca
Assistant Professor, Concordia University, Montreal, Quebec, Canada

Abstract
A construction project involves a wide range of technical and non-technical decisions to be made by individual and teams throughout the project lifecycle. Due to the short, medium, and long-term influence that decisions made (and their combination) have on the time, budget, and performance of a project, measuring decision making-related behavior in the Architectural, Engineering, Construction (AEC) is ultimately crucial. Unfortunately, the construction industry generally lacks tools to formally measure the decision making process. Aiming to fill this gap, recently a tool called Construction Decision Making Inventory (CDMI) is developed at University of Southern Mississippi. CDMI is a tool grounded on the science of decision making and knowledge/skills of the construction industry to measure the What? When? How? and Who? of decision making process in the construction industry. This paper presents early results from two case studies of applying the CDMI tool to evaluate decision making behavior of construction and architectural students in two universities in North America. The University of Southern Mississippi and George Brown College deployed the CDMI during the Spring 2016. We have used CDMI to compare the behavior of students with architectural and construction backgrounds across the two organizations. The results showcase some potential insights and added values that can be expected form employing CDMI. The early results are encouraging and important because they open the opportunity for researchers in other institutions to implement the CDMI tool and benefit from its results.

Keywords: Decision making analysis, case study, behavioral models, construction industry

1 Decision Making and Construction Industry
A variety of methods, tools and theories have been in use by the AEC industry for decision making. Those include from engineering judgment to mathematical tools and theories, to team and organizational decision making methods. Mathematical theories, tools and aids such as operation research, welfare economics, decision theory, mathematical programing, etc. are often used to map the subjective decision problems into objective/quantitative problems and then use mathematical methods to select the best alternative. In a comprehensive study, Jato-Espino, et al. (2014) reviewed 22 multi-criteria decision making tools (single and hybrid approaches) to assist axiomatic decision making in 11 major categories within the construction industry.

Most of such axiomatic decision models proposed in the literature try to mitigate the risk due to uncertain events in construction, or solve the multi-objective trade-offs such as time-cost-quality optimization in project planning (Monghasemi, et al., 2015 among others), or even to entertain more subjective criteria such as the sustainability of construction projects (Chen & Pan, 2016 and Govindan, et al., 2016 among others).

In order to explain the behavior of decision makers, attempts are made to develop decision making models for construction industry. These attempts normally employ theories from socio-phycology research. As an example, Parkin (1994) used the Social Judgment Theory (SJT), proposed by Sherif and Hovland back in 1980, and developed a 'power model' to describe the process of decision making in multi-stakeholder infrastructure mega-projects. Acceptability of an alternative in that model was correlated to the power level required to achieve a good fit between a proposed solution and the relevant social value structure of project stakeholders. In a more recent study, Nik-Bakht and El-Diraby (2015) reviewed 50 years of the published research on decision making in construction and offered a framework for analysis of decision making behavior in AEC. Their framework evaluates decision making based on the profile of decision makers, the decision tool used and the selection method followed.

The present paper reports a first step of a comprehensive study, aiming to understand and classify the behavior of professionals in the domain of construction, regarding decisions they make in their day to day business processes. For this purpose, first of all, a classification schema is required and then a tool is needed to classify decision making-related behavior within that classification schema. Last but not the least, samples will be required to reliably represent and describe the behavior of decision makers in the AEC industry. The paper introduces such a schema and explains the tool developed, called Construction Decision Making Inventory (CDMI), to measure decision behavior of professionals in construction, based on that. We also present a case study of applying the tool to two different samples of undergraduate and post graduate level construction students, and study the results.

2 Construction Decision Making Inventory (CDMI)

CDMI, recently developed by Dr. Tulio Sulbaran at the University of Southern Mississippi, measures four dimensions of the construction decision making process: What?, When?, How?, and Who?. The following is a brief description of the four dimensions:

What? – Results: Examines the perceived outcome of the decision making process. The CDMI classifies the results in this dimension as: 1- Satisfactory, designated as "SA"; 2- Inadequate, designated as "IN"; and 3- Between inadequate and satisfactory, receiving an "IS" designation as shown in figure 1.

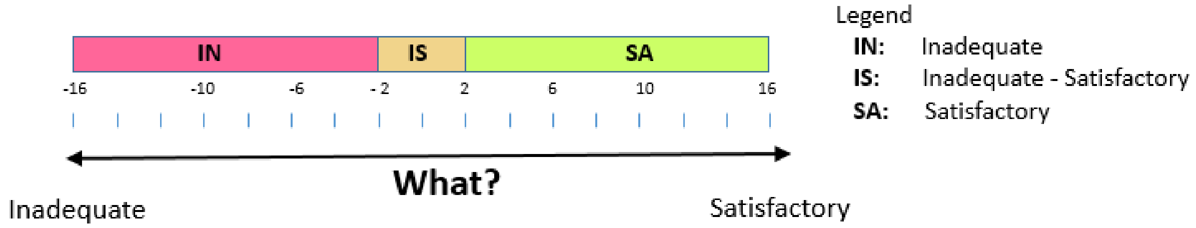


Figure 1 What? - Results Dimensions' Designation

When? – Timeframe: Focuses on the agility of decision process, reflecting the amount of time taken to make a decision. The CDMI classifies the results in this dimension as: 1- Deliberate, designated as "DE"; 2- Swiftly, designated as "SW"; and 3- Between deliberate and/or swiftly, receiving a "DS" designation as shown in figure 2.

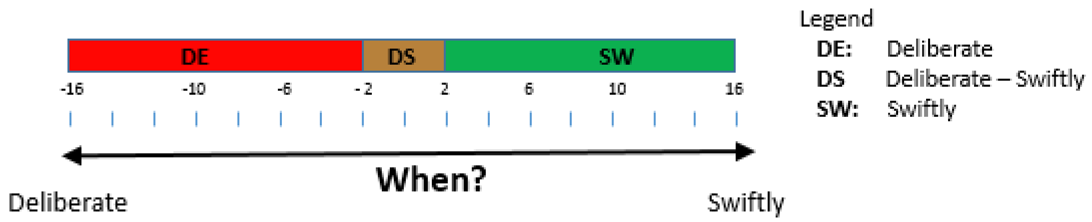


Figure 2 When? - Timeframe Dimensions' Designation

How? – Method: Appraises the approach followed to make decisions. The CDMI classifies the results in this dimension as: 1- Intuitive/Judgmental, designated as "IJ"; 2- Rational/Systematic, designated as "RS"; and 3- Between Intuitive and Rational receive an "IR" designation as shown in figure 3.

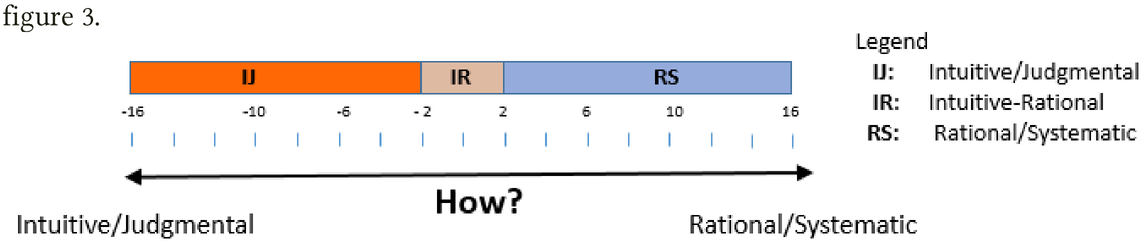


Figure 3 How? - Method Dimensions' Designation

Who? – Involvement: Looks in to the influence and/or reliance of decision maker on other people. The CDMI classifies the results in this dimension as: 1- Individual, designated as "IN"; 2- Group (Consensus/Consultation), designated as "GR"; and 3- Between individual and group receive an "IG" designation as shown in figure 4.

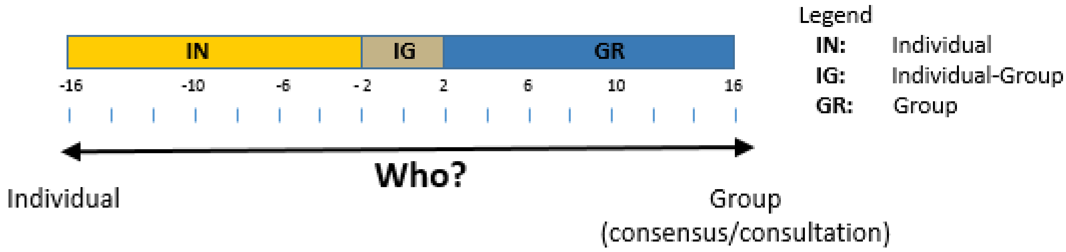


Figure 4 Who? - Involvement Dimensions' Designation

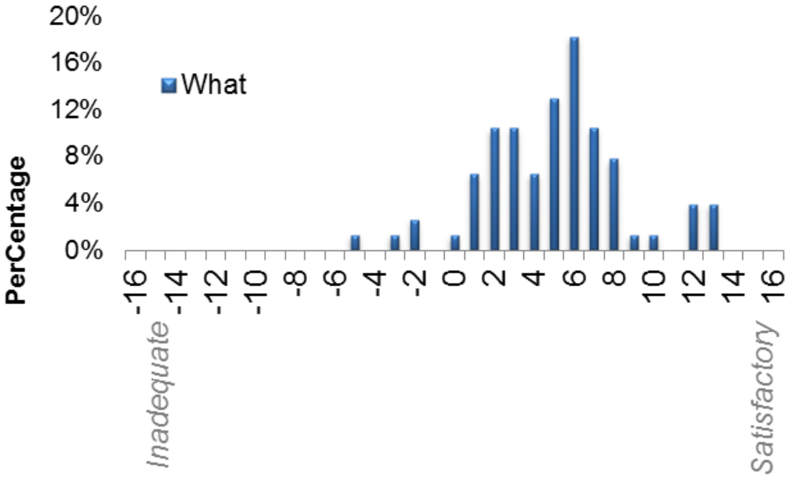
The CDMI is able to determine the four dimensions by processing 32 close-end questions. The questions are answered by the participants whom are given the option to answer by selecting from 5 choice liker scale ranging from completely false to completely true.

Since the CDMI is still at the initial phases of development, its statistical validity (accuracy of the assessment) and reliability (extent to which the results are consistent) need to be evaluated in practice. Thus, additional demographic and other questions have been embedded to the CDMI for this purpose. The validity and reliability assessment framework and studies are presented in detailed somewhere else (due to space limitations in this paper).

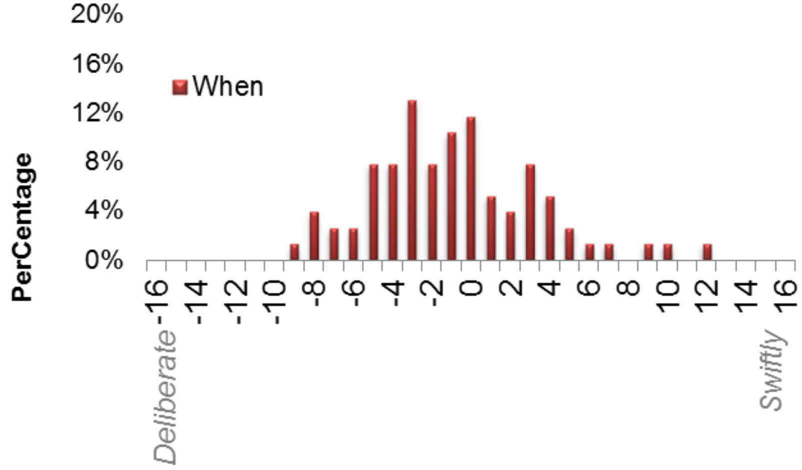
3 Analysis of Decision Making Behavior - Case Study

We applied the tool to two samples of students in undergraduate and post graduate programs of construction management in two different organizations in the United States and Canada. We surveyed those students in several rounds. Each survey also collected demographic and work-related information of attendants. The process and the results are introduced in this part.
University of Southern Mississippi in Hattiesburg, Mississippi (USM), USA and Angelo Del Zotto School of Construction at George Brown College (GBC), in Toronto, Ontario, Canada were the two organizations contributing to the case study.

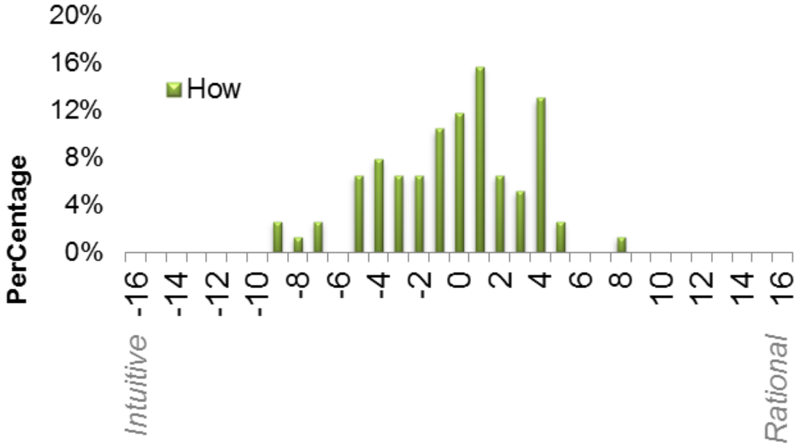
Participants at GBC were a group of post-graduate students (originally having Bachelor's or Master's degree in architect, construction or engineering), attending a three-semester program to attain a certificate on Building Information Modeling (BIM) Management. Students in this program come from ten different countries and have (mostly international) work experience as contractor, architect and engineering designer.



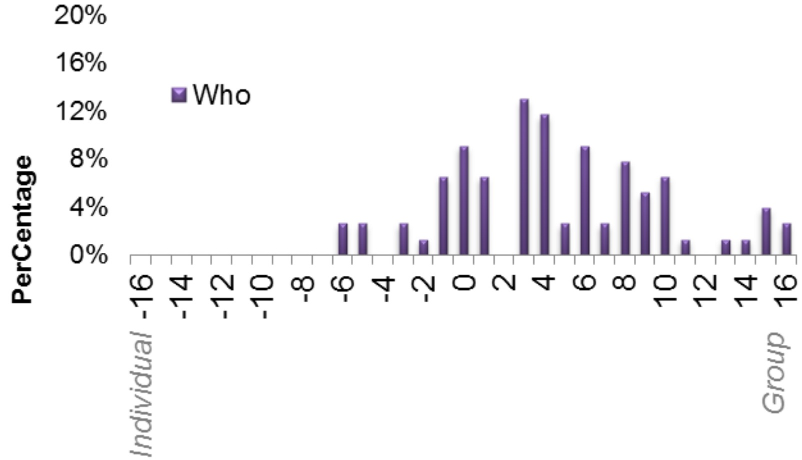
(a) CDMI What? - Results



(b) CDMI When? - Timeframe



(c) CDMI How? - Method



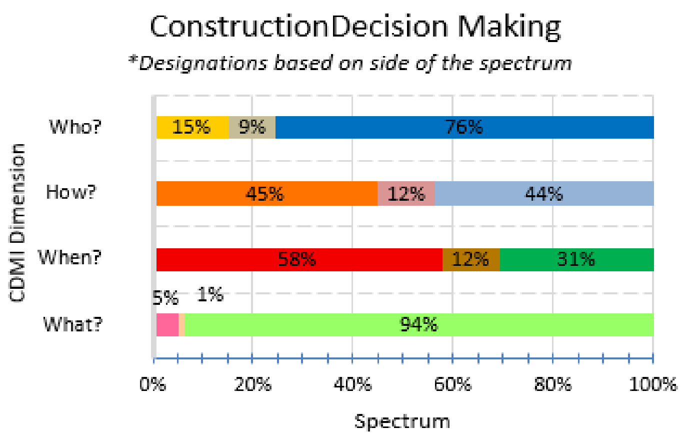
(d) CDMI Who?- Involvement

Figure 5 Distribution of CDMI results for all participants

Students participated in this study had a mix of professional background in construction, engineering and architect. A total of 42 construction-related and 33 architectural-related background (as well as two unrelated professional background) constitute our sample in this case study. among the participants with construction-related background, 14.3% were female and 85.7% were male; however, in students with architectural-related background 48.5% of participants were female and 51.5% were male.

Students in the two organizations participated in the cases study by responding to the CDMI questionnaire in two rounds. At each round, after submitting the responses, they were aggregated to evaluate behavior of participants (as decision makers) in the four CDMI dimensions. Figure 5 depicts the frequency distribution of results for all participants in the case study. The results are organized in the four CDMI dimensions. A rough visual scanning shows that while in most dimensions the behavior follows semi-normal distributions, some dimensions are closer to normal than the others. From the aspect of decision results (the “What” dimension) and involvement mode (the “Who” dimension), as seen, the distributions have a shift towards the positive half (‘satisfactory’ decisions/ ‘group’ decision making) with a single peak around the means. Time frame aspect (the “When” dimension), and method of decision making (the “How” dimension), on the other hand, have comparatively more symmetric forms, distributed in both negative and positive halves. This may suggest that decision makers in the construction industry use a mix of intuitive and rational decision making methods, and cover a wide range of decision making agility from deliberate to swiftly.

Figure 6 summarizes the results of behavior distributions in the four CDMI dimensions. As seen, while an absolute majority of participants have been group decision makers who are generally satisfied by outcomes of their decisions; there is a balance between those using rational/ systematic decision methods and those following intuitive/ judgmental decision methods. Last but not the least, the majority of participants makes deliberate decisions, nevertheless, there is a good portion of those who make their decisions swiftly. In all cases, a narrow portion of construction management students (five to fifteen percent) lie in between of the two ends of spectrums.



Legend

IN: Individual		GR: Group
IJ: Intuite/Judgmental		RS: Rational/Systematic
DE: Deliberate		SW: Swiftly
IN: Inadequate		SA: Satisfactory

Figure 6 What? When? How? and Who? designations for all participants

In order to compare the behavior of different samples (and sub-samples) studied in this project we performed statistical significance tests among samples and sub-samples. This included mean and variance comparison among: the sample of students in GBC (size: 40) versus USM (size: 37) as well as separate comparisons among students with construction background in the two organizations (size of 14 versus 28 respectively) and students with architect background in the two organizations (size of 25 versus 8 respectively). We performed t-test with 95% confidence interval to compare the means and Levene's test to compare the variances.

Our statistical tests show that the samples (and sub-samples) are generally exhibiting different behaviors in the three out of four dimensions evaluated by CDMI. Apart from the timeframe of decision making (the "When" dimension), the two samples (each of which being a mix of construction and architectural students) do not exhibit significant similarity among their distributions. This is the same when construction students in the two organizations are compared. But focusing on architecture students resulted in slightly different observations. Students with architect background in the two organizations did not show similar behavior (in terms of mean and variance of their distributions) with respect to the decision making timeframe. They, however, showed significantly similar distributions in terms of satisfaction level on the results of their decisions (the "What" dimension). This was a unique observation among the two samples and sub-samples. We repeated the comparison among the means with and without assumption of equal variances, both of which confirmed the same behavior in all cases.

Table 1 Statistical significance tests in case study samples

Major	University		CDMI What? - Results	CDMI When? - Timeframe	CDMI How? - Method	CDMI Who? - Involvement
Construction	USM	N	28			
		Minimum	-2.0	-9.0	-5.0	-6.0
		Median	5.0	-2.0	1.0	4.0
		Mean	**5.1**	**-1.8**	**.3**	**4.9**
		Maximum	13.0	5.0	5.0	15.0
	GBC	N	14			
		Minimum	1.0	-8.0	-9.0	-5.0
		Median	6.5	-3.0	.5	2.0
		Mean	**6.3**	**-1.4**	**-.6**	**3.0**
		Maximum	13.0	10.0	4.0	9.0
	Total	N	42			
		Minimum	-2.0	-9.0	-9.0	-6.0
		Median	6.0	-2.0	1.0	4.0
		Mean	5.5	-1.6	.0	4.3
		Maximum	13.0	10.0	5.0	15.0
Architecture	USM	N	8			
		Minimum	2.0	-4.0	-2.0	-3.0
		Median	5.0	-.5	.0	10.0
		Mean	**4.4**	**1.6**	**.9**	**9.1**
		Maximum	6.0	12.0	4.0	16.0
	GBC	N	25			
		Minimum	-3.0	-8.0	-9.0	-6.0
		Median	5.0	.0	-1.0	3.0
		Mean	**4.8**	**-.5**	**-1.2**	**3.1**
		Maximum	12.0	6.0	8.0	15.0
	Total	N	33			
		Minimum	-3.0	-8.0	-9.0	-6.0
		Median	5.0	.0	-1.0	4.0
		Mean	4.7	.0	-.7	4.6
		Maximum	12.0	12.0	8.0	16.0

Given the differences among distributions of decision-related behavior in different samples, we focused on mean and median of various groups to compare their behavior. Table 1 summarizes the results of such a comparison. We compare the behavior of different groups based on the statistics shown in this table, and by dividing each dimension into positive and negative halves only (i.e. the mixed area in the middle is ignored in this analysis).

4 Discussion and Concluding Remarks

This paper introduced the Construction Decision Making Inventory (CDMI) as a tool to evaluate behavior of experts and professionals in the field of construction, with respect to decision making. We also presented the result of two case studies at education level, in two North American education institutes, and with students of different professional backgrounds. Although this is only the beginning point of such studies, and the results can hardly be considered close to inferable, the method we presented can be directly used by other researchers in the domain and the aggregation of all outcomes may result in a deeper understanding of decision making behavior for the domain.

Figure 10 summarizes the observations of our case studies regarding behavior of construction students in the two educational organizations in the United States and Canada. Our results suggest that for these two organizations, students in construction program in general tend to make deliberate decisions; to make decisions in groups; and are generally satisfied with the outcomes of decisions they make. However, their professional background influences the approach they follow in decision making; while the Canadian students are generally intuitive and judgmental decision makers, students in the University of Southern Mississippi are leaning towards rational and systematic decision making approaches.

	Construction		Architectural	
	GBC(Canada)	USM (USA)	GBC(Canada)	USM (USA)
What	SA	SA	SA	SA
Who	GR	GR	GR	GR
When	DE	DE	DE	N/A
How	IJ	RS	IJ	RS

Figure 7 Summary of observations in our case studies within the two educational institutions

Given the differences observed in the behavior of students in different organizations/ programs, it will be worthwhile to repeat the experiment within more organizations. This will require contribution of more schools/ colleges/ universities all around the globe. The results will add value, not only to this study and improvement of CDMI, but also to both educators and learners in different institutions.

It must be noticed that given the size of samples, our results may not be applied to interpret the behavior of the whole populations of students; yet, what we presented here is a good starting point towards deriving a mental map of decision making for students in construction program. Upon gaining more maturity and passing validity and reliability tests, CDMI can be used as a tool for exploring professionals' behavior in the industry to achieve a better understanding on decision models and decision making behavior of the construction industry.

References

Chen, L., & Pan, W. (2016). BIM-aided variable fuzzy multi-criteria decsion making of low-carbon building measures selection. Sustainable Cities & Society.

Govindan, K., Shankar, K., & Kannan, D. (2016). Sustainable material selection for construction industry – A hybrid multi criteria decision making approach. Renewable & Sustainable Energy reviews, 55, 1274-1288.

Jato-Espino, D., Castillo-Lopez, E., Rodriquez-Hernandez, J., & Conteras-Jordana, J. (2014). A review of application of multi-criteria decision making methods in construction. Automation in Construction, 45, 151-162.

Monghasemi, S., Nikoo, M., Khaksa Fasaee, M., & Adamowski, J. (2015). A novel multi criteria decision making model for optimizing time-cost-quality trade-off problems in construction projects. Expert Systems with Applications, 42, 3089-3104.

Nik-Bakht, M. and El-Diraby, T. (2015). "Synthesis of Decision-Making Research in Construction." J. Constr. Eng. Manage.,

Parkin, J. (1994). A power model of urban infrastructure decision making. Ceoforum, 203-211.

Sherif, Muzafer (1980). Social judgment: Assimilation and contrast effects in communication and attitude change. Westport: Greenwood. ISBN 0313224382