

Measuring the Reliability of Construction Decision Making Inventory in Construction Management

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Construction is an industry that continually requires individuals and project teams to make important and impactful decisions during the delivery of a project. The construction professionals' decision-making process and their decision- making characteristics are areas mainly unexplored. In order to measure how construction professionals make decisions, previous research developed a decision-making tool called the Construction Decision Making Inventory (CDMI). The CDMI needs testing to make sure it produces quality, consistent, and reproducible measures to establish reliability. Therefore, the research team tested the CDMI tool with construction management undergraduate students (soon to be construction professionals). The distribution of the CDMI tool occurred once in November and once in December 2016 to the same student sample to collect data for analyzing the reliability of the CDMI. The research team used the Pearson Correlation Coefficient to determine the correlation coefficient of stability to find the reliability of the CDMI tool. The results of the study show that the CDMI measures are statically reliable, which verifies that over a period of time the CDMI consistently measures decision-making and provides a consistent representation of the decision-making characteristics of construction management students.

Key Words: Decision theory, Decision-making, construction management, stability reliability

Introduction

Decision-making involves thinking, judgment, and deliberate action with the purpose of achieving the desired objective based on a decision. A decision is a position, opinion, or judgment reached after a simple or complex evaluation. These decisions are also the outcome of implicit or explicit processes that assess potential consequences and uncertainties (Haidar, 2015). The construction industry, perhaps more than others, is plagued by poor decisions resulting in low performance with increased costs and time delays (An et al., 2005). Thus, decision-making is particularly important in the construction industry. Some of the decisions in the construction industry are relatively easy and straightforward, but many are very challenging due to numerous factors affecting a decision, including environmental conditions, human influences, and information availability. The nature of construction makes it challenging to make sound decisions due to factors such as, constant changes of the building environment, direct exposure to hazardous sources, high pressure on demanding schedules and costs, and increasing complexity of construction techniques. The goal of this project is to investigate decision making in construction professionals.

Previously conducted research developed various construction decision-making models. However, the measurement of individual's decision-making process has mainly been unexplored. Thus, an innovative tool called the Construction Decision Making Inventory (CDMI) was developed to measure the "What, When, How, and Who" of the decision-making process. As an innovative tool, it requires proper testing. Thus, the specific objective of this paper is to present the results of a reliability test performed to the CDMI using undergraduate students in a construction management program at a public institution in the United States.

Background

To understand decision-making, one has to look at the underlying reasons that a person or persons makes the decision that they made. Decision theory is the area of science that is concerned with the reasons that underlies a person's choices. Personal emotions, beliefs, desires, and values can influence the thinking that a person uses in a decision, which then embodies that decision theory is not only concerned with the theory of choice, but also a theory of behaviors and attitudes that coheres with making a decision (Steele & Stefánsson, 2015).

Research on making decisions has been conducted for many years by multiple disciplines resulting in a wide range of and diverse decision-making models. Depending on their methodological foundation, one can classify decision-making models as descriptive, prescriptive, or normative. The decision-making models can also be either non-compensatory or compensatory. Table 1 summarizes both groupings, which outlines their focus and description.

Table 1

Difference between Decision-Making Model Methodologies and Classifications

Model	Focus	Classification	Classification Description
Descriptive	What people actually do, or have done	Non-Compensatory	Once alternatives have been eliminated based upon the single attribute evaluation, they cannot be assessed on any other attribute regardless of their performance on these subsequent attributes.
Prescriptive	What people should and can do	Compensatory	Implies that a decision maker will trade-off between a high value on one dimension of an alternative and a low value on another dimension.
Normative	What people should do (in theory)		

One example of a decision-making theory/model is game theory. Game theory is the study of conflict and cooperation interactions between intelligent, rational decision-makers whose decisions can affect one another (Myerson, 1991). In essence, game theory is an interactive decision theory as a *game*, in this case, refers to any social situation that involves two or more individuals, which in the context of construction the social situation would be the construction project itself and the associated project team.

In the case of construction projects, project participants make many minor decisions each day that involve one or a few participants and results in limited impact or consequences to the project. Other decisions made by the project team can substantially affect the performance and potential of achieving a successful outcome such as deciding to delay a critical path activity due to unforeseen site conditions. Proper decisions during the planning phase of a construction project help reduce the number of difficult decisions that need to occur once the project is under construction. However, many times projects do not proceed as planned due to unexpected circumstances, making these projects not so easy to predict or control. In those cases, project participants need to make many more difficult and impactful decisions throughout the construction phase (Ashley et al., 1983). Nevertheless, making these decisions can be much more difficult if one does not understand the implications of the choice made.

In addition, decision-making in construction is becoming increasingly more difficult due to complexities such as alternative delivery methods and the ever-increasing size of construction projects today. A research study conducted by Medda (2007) utilized game theory to study the complicated process of arbitrating risk allocation in transportation public-private partnership (PPP) projects. In this study, the author created a simulation using game theory that models risk allocation choices in PPP projects called the "final offer arbitration game." The final offer arbitration game allowed for analysis of the agents' behaviors when confronted with opposing objectives. This game framework examines the allocation of risks as a bargaining process between two individual agents when confronted with decisions about risk allocation for a PPP project. In the game, the agents compete with one another to achieve the most reasonable offer in settlement of risk allocation. The results of the study showed that more risk-averse agent tend to submit a more reasonable final offer and it has a higher probability selection as the final offer by the arbitrator. Additionally, when the guarantees an agent is willing to give to the other exceed the financial loss related to the risk, the less risk-averse agent then has the higher selection probability.

In addition to the complexities associated with delivering construction projects and making critical decisions nowadays, social and business influences, as well as traditional technical components of construction projects, tend to influence the decision-making environment in the construction industry:

- On the technical side: new practices, such as sustainability, compound decisions by introducing new environmentally friendly decision criteria.
- On the business side, globalization of the construction industry is changing competition between contractors at the local, regional, national, and international levels.
- On the social side: stakeholders, the public, and the potential users of a project have their own set of needs and wants that a project should support once it is completed (Bakht & El-Diraby, 2015).

Based on the numerous technical, business, and social factors considered in the decision-making realm of construction, there is a need to explore the process of making decisions and the reasons for making a decision. Furthermore, it is important to note that selecting a choice is just one portion of the decision-making process, while the other is the knowledge and expertise to make a *good* choice. One needs to comprehend what the advantages and consequences are in making a decision. Due to the complex and challenging nature of making decisions during construction of a project, researchers and practitioners developed various decision analysis tools in terms of methodologies and decision support systems that rely on computers and algorithms to help individuals and project teams to make better decisions (Clemen & Reilly, 2014). A decision that enhances the project and results in minimal or minor consequences is a worthwhile decision. However, getting to the point that a person or project team can make a good decision may not be an easy task.

According to Russo and Shoemaker (2002), a four-stage process for making decisions captures the primary aspects of making a sound decision:

1. Framing: Framing of decision-making determines the viewpoint from which the decision makers use and sets the parameters of the critical aspects to consider for the situation. Framing helps to dictate what criteria to use in order to cause the decision makers to prefer one option to another.
2. Gather Intelligence: Collect all pertinent known information, including the use of internal and external sources of data. Additionally, the decision makers have to evaluate any unknowns or assumptions due to the uncertainty involved in the decision. It is important during this step to avoid biases by only collecting and focusing on data that confirms their beliefs. It is best to be as impartial as possible.
3. Make Conclusions: The framing and collected information does not guarantee a good decision, but helps set the stage for an analytical approach. The use of intuition or a "gut-feeling" tend not to result in consistently good decisions. A systematic approach to making a decision results in choices that are more accurate. The decision makers must rely on the information collected, the understanding of uncertainty in the decision, and working together to find the best choice that has the least consequences.
4. Learn from Experience: Review the outcomes of the implemented choice to understand if the choice was the ideal decision and collect lessons learned useful for future decisions. This review process is the best way for an individual or a team of decision-makers to learn from their decision to improve how to make a decision in future choices.

Making a sound decision improves when using a decision-making process similar to what the authors described above. However, several issues make decision-making challenging, which people need to be aware of that can prevent making effective and reasonable decisions. Russo & Shoemaker (2002) noted the following challenges in decision making, which includes having too much information, the reality that important decisions need to be made frequently, conflicting goals of the decision makers, fewer opportunities to correct mistakes, and the fact that construction is a high risk, low profit margin industry.

Overall, one can see the importance that comes from making decisions and the reasons why many previous studies have focused on developing methods and decision support tools to assist the construction industry in making decisions (e.g., Hazir 2014; Tran et al., 2013; Ashley et al., 1983). However, these studies focused on assisting with the decision-making process itself and not on how people within the construction industry make decisions. Additionally, these studies did not investigate how people make decisions or how to measure the decision-making characteristics of construction industry professionals. Therefore, the objective of this paper is to develop and analyze a decision-making tool called the Construction Decision-Making Inventory and to determine the reliability of these measures so that future research can impose the CDMI to find out what the decision-making abilities are for the team involved in a construction project.

Description of the CDMI

The development of the CDMI is a vital step in determining the decision-making process of practicing professionals and students in the construction sector. The CMDI is grounded on three pillars: 1- Psychometrics, 2- Science of decision-making, and 3- Construction industry knowledge management and best practices.

Psychometrics is the science of psychological assessment that applies equally to assessment in education and other areas (Rust, 2009). Psychometrics involves two primary tasks: 1) the construction of measurement instruments, and 2) the development of procedures for measurement. It is concerned with the theory and technique of psychological measurement. The construct of instruments focuses on the objective measurement of skills and knowledge, abilities, attitudes, personality traits, and educational achievement.

The science of decision making is one of the fundamental cognitive processes of human behaviors by which a preferred option or a course of action is a result of making a choice from among a set of choices based on specific criteria (Wang & Ruhe, 2007). Many different disciplines perform research on decision-making, from mathematics and statistics, through economics and political science, to sociology and psychology. The study of decisions addresses both normative and descriptive questions. The normative analysis is concerned with the nature of rationality and the logic of making a decision. The descriptive analysis, in contrast, is concerned with people's beliefs and preferences as they are, not as they should be. (Kahneman & Tversky, 2000).

Construction industry knowledge management and best practices are two interrelated concepts for the construction industry. Knowledge management refers to the creation of a thriving working, learning environment that fosters the continuous creation, aggregation, use, and re-use of both organizational and personal knowledge in the pursuit of new business values (Anumba et al., 2005). Best practices are the policies, systems, and procedures that, at any given time, are generally regarded by peers as the practice that delivers optimal outcomes, such that they are worthy of adoption (The Constructor, n.d).

The CDMI is in the early stages of development, and this research represents the first attempt to measure the "What, When, How, and Who" dimensions of the construction decision-making process. The CDMI tool is composed of 32 closed-end questions plus 20 additional closed-end questions from the rational-experiential inventory that the researchers used in the reliability and validity evaluations (Sulbaran and Nik-Bahkt, 2016). All the closed-end questions use a five-point Likert scale ranging from "Completely false" (1) to "Completely True" (5). The participants selected only one choice for each question. Responding to all of the CDMI questions take less than 15 minutes for participants to complete/answer. Table 2 provides a sample list of the CDMI questions.

Table 2

Sample list of questions in the CDMI

CDMI Closed-end questions	Rational-experiential Inventory Questions
I generally make important decisions at the last minute	I believe in trusting my hunches
I regret the results of my decisions	I'm not that good at figuring out complicated problems
I make decisions in a logical and systematic way	I have no problem thinking things through carefully
I rarely make important decisions without consulting other people	I can usually feel when a person is right or wrong, even if I can't explain how I know
I generally make decisions that feel right to me	I am much better at figuring things out logically than most people

The participant answers are used to calculate the four dimensions determined by the CDMI (e.g., What, When, How, and Who). Each of the four dimensions was appraised on a uniaxial scale. The uniaxial scale has two diametrically opposite poles allowing assessment of a participant within the range of the poles, as shown in Figure 1.

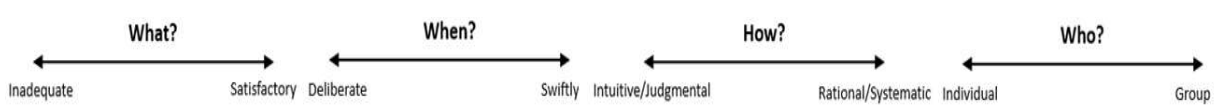

Figure 1: Uniaxial Dimensions Measured by the CDMI

CDMI Reliability Research Method

This research project followed a case study research method. This research method enables the close examination of the data and allows one to describe the data as it occurs (Zaidah, 2007). Both of these elements are key to determine the stability reliability of an instrument such as the CDMI. The case study process used the steps described below.

1. Determine/define research question: The main question addressed by this research project was whether the CDMI tool was reliable regarding stability.
2. Select the case: The researchers used a single case study to assess the reliability of the CDMI tool and its questions. This methodology was used as the first test of measuring the reliability of the CDMI. The selected case was students from a higher education university within a construction management undergraduate program in the United States.
3. Prepare to collect the data: An invitation e-mail was prepared to describe the project and the option for the students to participate or not. The CDMI instrument is an online tool, and therefore it was ready for electronic distribution. After distributing the data, follow-up e-mails were sent to students that had not yet participated.
4. Collect data in the field: The students in the study received an e-mail and the CDMI instrument to elicit information electronically. The authors also sent two reminder emails over the course of three weeks to the students. Then, a second round was conducted to collect data for evaluating stability reliability of the CDMI.
5. Evaluate and analyze the data: The "What, When, How, and Who" dimensions of decision-making are assessed based on the 32 closed-end questions found within the CDMI. The calculation of each dimension used a subset of eight questions. The authors then transferred the collected data to the statistical software package SPSS, where the authors then calculated the dimensions of each participant for both rounds.
   The reliability type used in this research and presented in this paper correspond to "Stability" which measures the consistency between the results of two evaluations of the same participants. The stability reliability analysis conducted investigated the dimensions and the individual questions using the Pearson Correlation Coefficient.

Results, Analysis and Discussion

The emphasis of the analysis was to determine the stability reliability of the CDMI tool and the associated individual measures (e.g., the questions). Reliability is an integral part of developing measurable variables that are consistent and measure what one intends to measure with limited error, as reliability is the opposite of measurement error. In contrast to validity, reliability looks at how variables are measured rather than what is measured (Hair et al. 2010).

Following the methodology described above, 110 undergraduate construction management students from a flagship state university received the first round of the CDMI tool in early November 2016. Then, in December 2016, the same set of undergraduate construction management students received the CDMI tool for the second round of distribution. The CDMI tool also included demographic questions for the participants to complete. Table 3 summarizes the breakdown of the students who participated in round one and round two.

Table 3

Breakdown of the students who participated in round two of the CDMI tool deployment

		Round One (N = 75)	**Round Two (N = 68)**
Gender	Male	69	63
	Female	6	5
Age	18-22 years old	53	51
	23-27 years old	21	16
	28-32 years old	1	0
	33-37 years old	0	1
Construction	None	11	7

Experience	Less than 1 year	25	31
	1 to 5 years	37	28
	5 plus years	2	2

Table 4 summarizes the total number of students that participated in *each round* of the CDMI tool distribution along with the descriptive statistics for the decision-making dimensions. In all, the first round experienced a response rate of 68% and the second round experienced a response rate of 62%. Overall, 53 students completed both the first round *and* the second round, which represents the sample size used in the analyses.

In a review of the descriptive statistics, the mean values of the first and second round for each one of the dimensions are very similar. The mean values represent the overall characteristics of the participants in each of the appraised dimensions on the four uniaxial bipolar scales shown in Figure 1. The negative and positive values in the bipolar scale do not have a negative or positive connotation; rather they denote the left and right side of the bipolar scale. The two scale poles represent various decision-making approaches, ranging from an individual that is analytical and deliberate in their decisions to an individual that makes decisions swiftly and based on gut feeling. For example, a "Who" value of 4.21 indicates that the participants prefer to make decisions involving others, or as a group.

Table 4

Descriptive Statistics for the four dimensions of the CDMI

Dimension	Round One Mean	Round One Std. Deviation	Round One Sample Size	Round Two Mean	Round Two Std. Deviation	Round Two Sample Size
What	5.23	3.126	75	5.16	3.357	68
When	-1.97	3.738	75	-1.54	4.467	68
How	0.81	2.958	75	1.09	3.295	68
Who	4.21	4.709	75	4.44	4.123	68

Then, using the Pearson Correlation Coefficient, referred to as the coefficient of stability for test-retest reliability (R), the research team compared each of the dimensions from the first round to the second round of the CDMI questionnaire. Table 5 summarizes the sample size for each correlation analysis, the coefficient of stability, and the associated p-value/significance for each of the four dimensions.

The coefficient of stability values show the decision-making dimensions to be significant (p-value = 0.000) and that the R-value is positive, meaning that a significant positive correlation exists between the collected first round and second round data of the CDMI tool across all the decision making process dimensions. The R-values range from 0.560 to 0.718, based on the type of data, indicates acceptable reliability. Therefore, the CDMI tool achieved sound stability reliability regarding the four dimensions of the construction decision-making process.

Table 5

Stability Reliability of the four Dimensions of the CDMI

Dimension	N	Pearson Correlation (R)	Significance (2-tailed)	Coefficient of Determination (R^2)
What	53	0.560^{**}	0.000	0.314
When	53	0.694^{**}	0.000	0.482
How	53	0.656^{**}	0.000	0.430
Who	53	0.718^{**}	0.000	0.516

In terms of achieving acceptable reliability, there exist many sources that state various acceptable values for the coefficient of stability in order to establish reliability. However, few, if any, standards exist for interpreting the minimum acceptable value for the coefficient of stability in test-retest reliability analyses (Crocker & Algina, 2008). Even the American Psychological Association (APA) Dictionary of Statistics and Research Methods (2014) does not include a standard under retest reliability. The coefficient of stability for test-retest reliability is a difficult value to standardize due to factors as the time between tests, the length of the test, the type of participants that make up the sample, what one intends to measure, and the characteristics of the sample participants (Murphy & Davidshofer, 2005). People's traits can remain constant or change, which then has the possibility of introducing uncontrollable measurement errors that lead to lower, but acceptable, reliability stability coefficients (Crocker & Algina, 2008).

Some sources state their perception of what, in general, acceptable reliability happens to be, which typically states a range of 0.7 and above as good reliability (e.g., Murphy & Davidshofer, 2005; Urbina, 2004). However, other sources that focus on the reliability of attitudes and personality may state values of 0.5 to 0.8 as being acceptable reliability (e.g., Buckley et al., 1990). Achieving the higher levels of stability assumes quite a bit about the data set. As Roszkowski & Spreat (2011) state, data sets used for research purpose rather than datasets used for say standardize, testing can achieve lower levels of reliability that are acceptable. In addition, data sets used for measuring traits can achieve acceptable lower levels of stability reliability when compared to data sets used for placement testing. Since the data used is for research purposes and not for standardized testing, and the CDMI tool describes decision-making traits and not a placement exam tool, the coefficient of stability values are acceptable.

To further define and evaluate the stability of the CDMI tool, next step was to analyze each of the 32 questions for stability reliability to find any questions that represent outliers or questions that are inconsistent over time and in reproducibility of results. Table 6 outlines the results in which the majority of the questions (25 out of 32, or 78.1%) achieve stability reliability at or below the 0.01 significance level for type I error. Furthermore, an additional five questions (30 out of 32, or 93.8%) achieved stability reliability at the 0.05 significance level. The remaining two questions showed a weak or no correlation between the first round and second round responses. One of the questions was from the "How" dimension as, "I generally make decisions that feel right to me." The other question was from the "Who" dimension as, "If I have the support of others, it is easier for me to make important decisions."

Table 6

Stability Reliability for each of the questions within the four CDMI Dimensions

Dimension	**Number of questions**	**Number of questions with correlation at 0.01**	**Number of questions with correlation at 0.05**	**Number of questions with weak or no significant correlation**
What	8	6	2 (a, d)	--
When	8	7	1 (e)	--
How	8	5	2 (b, c)	1 (f)
Who	8	7	--	1 (g)
Total	**32**	**25**	**5 (a, b, c, d, e)**	**2 (f, g)**

Based on the individual question results, 30 of the 32 questions resulted in high stability reliability with a significant p-value of 0.05 or less. The remaining two questions did not establish stability reliability and were found not significant. Therefore, although the CDMI as a whole is considered to be reliable, it is recommended to modify the two questions showing no significant correlation to better contribute to the CDMI.

Conclusion

The CDMI is a tool that is a reliable instrument to measure decision-making characteristics of construction students, who soon will be construction professionals. As this is a newly developed tool, the CDMI required testing to ensure the tool measured what it intends to measure and that the responses were true measures of decision-making with as little measurement error as possible. The analysis of stability reliability shows reliability of the CDMI tool and most of the individual questions, which means the tool is consistent and stable in what it intends to measure, the decision-making abilities of construction professionals.

While conducting the research, the authors acknowledge limitations to this research as well as the potential for future research studies. As this research explored the stability of the CDMI tool, construction management students from higher education participated in the study. Although the test did establish the reliability of the CDMI tool, the tool intends to measure decision making of construction professionals. Future research is focusing on establishing the validity of the CDMI tool, but ultimately, the tool needs to be deployed to experienced construction professionals to help understand the nature of decision making in the construction industry. In addition, further reliability and validity testing are ongoing with the CDMI, which will be presented in future research.

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