Construction Decision Making Inventory (CDMI) – Assessment Framework for Validity and Reliability

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

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

Abstract

Decision making is the art and science of selecting the alternative with the most favorable/desirable payoff, among a set of alternatives available, and under the constraints and consistencies governing the selection problem. Professionals in the construction industry are faced with several decision points on a daily basis. Many of the decisions made by construction professionals are irreversible and may have long lasting impacts on the project success. Moreover, multiplicity of the objectives, complexity of causal dependencies to predict consequences of each decision alternative, and the lack of information (or knowledge) at the point of decision are among other factors which make decision making in construction industry critical and complicated. Despite all former efforts, construction decision making as a "process" is less explored and the industry is lacking a reliable instrument to measure and evaluate the performance of decision making. A tool called "Construction Decision Making Inventory (CDMI)" was recently developed at the University of Southern Mississippi to fill this gap. CMDI is grounded on the science of decision making and knowledge/skills of the construction industry and is the first attempt to measure the What? When? How? and Who? of the construction decision making process. This tool is still at the initial phases of development and therefore its statistical validity (accuracy of the assessment) and reliability (extent to which the results are consistent) need to be evaluated in practice. This paper presents the multi-institution framework that will be used to set up a group of case studies to assess the CDMI's validity and reliability. Test participants include construction students in the United States and Canada. The results of this study are essential for portraying the future paths in development of the CDMI to increase reliability and validity of its outputs prior to releasing the CDMI for broad implementation worldwide.

Keywords: Decision making analysis, reliability, validity, framework

1 Introduction

According to Linstone (1984), decisions in a multi-actor enterprise are usually made in one of the three forms: 1- Personal (based on the judgment of a powerful key player); 2-Technical (finding the optimum solution based on technical analyses provided by individuals); or 3- Organizational (emerging from initial individual judgments). Construction profession entails decision making through the complete project lifecycle. Depending on the phase of the project lifecycle, a variety of managerial skills, quantitative judgments and qualitative analyses may be required to select the most favorable alternative among the available ones. The complexity of these decisions is increased since incomplete information at decision points, multitude of uncertainty sources governing construction projects, multiplicity of decision makers and dynamism of their interests are commonplace in the construction industry.

Modern project delivery methods add to this complexity by adding to the number and subjectivity of decision criteria. These methods are also re-shaping the project governance from a controlled hierarchy to a network of project actors and stakeholders along with their vested interests, power and authority levels, norms and standards, etc. This is changing decision making from a controlled/structured project into a distributed/bottom-up process in which the final decision 'emerges' from the contribution of multiple agents/actors (Bruijn & Heuvelhof, 2000). Such a paradigm shift is attracting the attention of both researchers and industry practitioners to develop models for supporting the decision making process in construction industry.

Apart from the wide range of technical decisions at different phases of planning, design, construction and operation, the construction industry is deeply involved in making managerial decisions. Looking at a project through its lifecycle, some of these decisions include: project budgeting and financing, selection of project delivery method, bidding- tendering and contractor selection, project planning and control, resource allocation, procurement, site management, equipment management, and facility management.

Over the years, multiple decision making models have been developed. The main aim of decision models is to help making better decisions through accurate predictions or optimization of the choices' outcomes. Table 1 provides a brief overview of some decision making models which are more common in the construction industry, along with sample research projects highlighting the implementation of each model. We used the terminology proposed in 1996 by Parkin to provide the overview of decision making models. Parkin (1996) suggested to classify the decision making models in the construction industry into three broad categories: 1- Axiomatic, 2-Judgmental and 3-Organizational.

Table 1 Sample decision making models developed in construction industry

	Axiomatic Decision Models	*Judgmental Decision Models*	*Organizational Decision Models*
Foundation	Operation research; welfare economics; decision theory; mathematical programming; etc.	Human judgment and decision behavior; socio-psychological research and theories; social judgmental theory; etc.	Negotiations, argument, persuasion, trust, and other complex social interactions among decision makers
Sample studies	Hatush et al. (1998); Palaneeswaran et al. (2001); Topcu (2004); Jato-Espino, et al. (2014); Monghasemi, et al., (2015); Chen et al. (2016); Govindan, et al. (2016)	Parkin (1994); Tang et al. (2010); Mukherjee et al. (2009); Lu, et al. (2016)	Heravi et al. (2014); Alhumaidi (2015); Luoma, 2016)
Typical applications	Mitigate the risk due to uncertain events in construction; solving multi-objective trade-offs such as time-cost-quality optimization; etc.	Policy making & strategy development; studying limitations of the human mind, stressfulness of decision process, heuristics and biases, acting on the basis of images and goals; etc.	Construction mega-projects with multiple stakeholders; contractor selection based on criteria/inputs of multiple stakeholders; time-cost-quality trade-off in project team setups; etc.
Weak points	Oversimplifying the reality	Conflicting norms and interests of multiple decision makers	Chaotic nature – benefits contingent on context-specific parameters such as the task, individuals involved, organizational and environmental factors

Regardless of which class of decision model to be selected and what tools to be used for supporting it; modeling the behavior of professionals in the process of decision making is appealing. One of the main requirements for such studies is to understand their logical basis in the selection process, within a specific context. For example, in order to understand top parameters influencing the decision of whether to bid on a project, Lesniak & Plebankiewicz (2015) surveyed a large number of contractors and concluded that type of work, experience, and contractual terms are the top factors in their judgmental model.

Unfortunately, most of the research projects are model, process and/or project specific and not much generalization can be safely assumed from the results. Construction Decision Making Inventory (CDMI) is a tool created to fill this gap. This tool in introduced in the next part; though in order to complete the review on the works done, here we summarize the three main classes depicted in table 1, within the main dimensions of CDMI: Who, When, How and What. This is done in table 2.

Table 2 A summary of Who, How, what of different decision models

	Axiomatic	Judgmental	Organizational
Who	[Normally] individual	Individual/Multiple	Multiple/Group
When	Deliberate/Swiftly	[Normally] swiftly	[Normally] deliberate
How	Simplified Model ↓ Predicted Outcomes ↓ Selection	Thoughts/evidences ↓ Judgment ↓ Decision	Initial Judgment ↓ Network Interaction ↓ Final Judgment
What	Technical & Tactical	Strategic & Policy Making	Cooperation & Competition

Unbiasedness and reliability are two of the main reasons that allow decision models to outperform the human (Rosenzweig, 2014). Firstly, decision models avoid biases that determine human judgments. Secondly, unlike the human, a decision model always gives the same answer to the same question. Therefore, in order to understand the human decision making process, extra attention must be paid to these aspects of professionals' judgment.

2 Construction Decision Making Inventory (CDMI) Overview

Despite all former efforts on developing decision making models and research projects exploring the models' implementation in the construction industry, construction decision making as a "process" is mainly unexplored and the industry is lacking reliable instrument to measure and evaluate it. In response to the demand for filling this gap, a tool called "Construction Decision Making Inventory (CDMI)" was recently developed by Dr. Tulio Sulbaran at the University of Southern Mississippi. The construct and characteristics of the CDMI are provided and discussed in detail somewhere else (due to space limitations in this paper). In short, the CMDI is grounded on the science of decision making and knowledge/skills of the construction industry presented above and other theories and instruments. The CDMI is currently composed of 32 close-end questions with a 5 choice liker scale ranging from completely false to completely true. The participants select one of the choices in each of the questions. The answers are then used to calculate the four dimensions determined by the CDMI. These four dimensions are What? When? How? and Who? of the construction decision making process. Each of the four dimensions is appraised on a uniaxial scale. The uniaxial scale has two diametrical opposite poles allowing to assess a participant within the range of the poles. The following is a brief description of the four dimensions:

- **What?** Examines the perceived outcome of the decision making process
- **When?** Focuses on the amount of time taken to make decision
- **How?** Appraises the approach followed to make decisions
- **Who?** Looks in to the influence and/or reliance of decision maker on other people

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 focus of this paper is to present the multi-institution framework that will be used to set up a group of comprehensive case studies to assess the CDMI's validity and reliability. The participants sample currently includes a group of construction students at different levels, in the United States and Canada. Professors around the globe are welcome to join the research effort by implementing the CDMI and assessment framework in their corresponding institutions.

3 CDMI Assessment framework

This section explains the assessment framework that will be used to determine the validity and reliability of the CDMI. Firstly, well-established validity methods are presented and associated with the validation of the CDMI. Then, well-grounded reliability methods are presented and also associated with the reliability assessment of the CDMI.

3.1 CDMI Validity Evaluation

Validity is the level to which inferences from the assessment results are justifiable, relevant and meaningful. Validity refers to the degree to which a survey instrument assesses what it purports to measure (Fink, 1995). Survey validity refers to the degree with which the inferences based on survey scores are meaningful, useful, and appropriate. Thus, survey validity is a characteristic of the survey which refers to its accuracy; the higher the accuracy of survey results to the intended purpose, the higher the validity of survey instrument (as shown in figure 1).

Lower Validity Vs Higher Valididty

Figure 1 Schematic concept of validity

3.1.1 Assessment of Validity

Validating a survey instrument entails accumulating empirical data and logical arguments to show that the inferences are indeed appropriate (Brualdi, 1999). There is an extensive literature (mainly for theories in psychology and educational assessment) focusing on validating methods to assess the performance of survey instruments. The methods listed in literature include:

1. Face Validity: refers to the degree to which an assessment or test subjectively appears to measure the variable or construct that it is supposed to measure (Williams, n.d.). Face validity does not rely on established theory for support (Fink, 1995)
2. Content Validity: is a subjective measure of how appropriate the survey items seem to a set of reviewers who have some knowledge of the subject matter (Litwin, 1995). It relates the ability of the questions to reflect the issue under research and make sure that key related subjects are included. (Mora, 2011).
3. Criterion Validity: is a measure of how well one instrument stacks up against another instrument or predictor (Litwin, 1995). Criterion validity may be divided into two components: concurrent and predictive validity.
4. Construct Validity: is often determined only after years of experience with a survey instrument. It is a measure of how meaningful the scale or survey instrument is when used in practice. It measures performance of a survey instrument in multitude of settings and populations over a number of years (Litwin, 1995). Construct validity is established by looking at numerous studies that use the test being evaluated. (Williams, n.d.). It is the extent to which an instrument measures a characteristics that cannot be observed directly but must instead be inferred from patterns in people's behaviors (Leedy & Ormrod, 2015). Construct validity may be divided into two forms: convergent and divergent/discriminant.

In short, testing the validity of a survey instrument is more similar to hypothesis testing than a calculation (Litwin, 1995). Thus, it is recommended to validate the instrument through more than one type of validation method.

3.1.2 Methodology to Assess the CDMI Validity

It is important to validate the CDMI to ensure that its results are relevant, meaningful, useful and appropriate to measure decision making in the construction industry. Over time, the Construction Decision Making Inventory (CDMI) will be validated using the four validity types: Face, Content, Criterion and Construction. Outputs of each validation measure will be looped back to improve the CDMI. After each step of improvement, the CDMI will be validated again through all previously completed validation methods. So, for example, if the CDMI is improved as results of the criterion validation, then the improved CDMI will be validated again through the face, content and criterion method as shown in Figure 2.

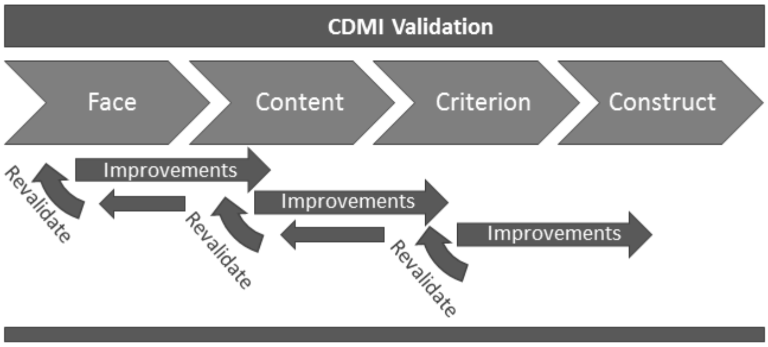

Figure 2 CDMI Validation Methodology

Each validation measure will be applied through a series of independent but inter-related research projects. Each research project will follow a quantitative descriptive methodology and/or qualitative case study methodology. Quantitative descriptive methodology will be used because it will allow identifying the characteristics of the CDMI and exploring possible correlations. The quantitative descriptive methodology does not involve changing or modifying the situation under investigation (in this case decision making process), nor is it intended to determine cause-and-effect relationships (Leedy & Ormrod, 2015). The qualitative case study methodology will be used because the CDMI is a new tool and very little is known about its performance. The qualitative case study methodology is especially suitable for learning more about situations which are poorly understood (Leedy & Ormrod, 2015).

The number of participants, demographic characteristics and validation protocol will vary from a research project to another, depending on the partnering researcher(s) and the type of validation. Since it is anticipated that most of the initial validation cycles will take place in academic institutions, it is expected that each research project will have between 15 and 60 participants. The data for research projects is collected electronically using an on-line survey system and will be stored in a centralized database. The data stored will be analyzed using mainly descriptive statistics.

For the face and content validity, the participants will be provided with a CDMI validating instrument. The main purpose of this instrument will be to elicit the participants about the validity of each question, measuring the What? When? How? and Who? of the construction decision making process as shown in Figure 3. For the criterion validity, the CDMI will be deployed and the results will be compared against other psychometric instruments such as the Rational

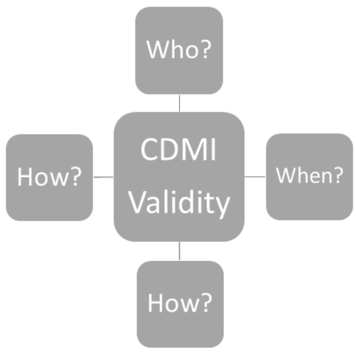

Figure 3 CDMI Validity Instrument

Experimental Inventory (REI), Learning Styles, etc. For the construct validity, after approximately 2 to 4 years of CDMI implementation, the implementers will be asked to share their experiences using the CDMI particularly on: 1- How they are using the CDMI results; and 2- The meaningfulness of the CDMI's scales to measure the What? When? How? and Who? of the decision making process.

Table 3 presents a synopsis of the four types of validation with their corresponding characteristics, CDMI validation implementation and the expected result metrics.

Table 3 Construction Decision Making Inventory (CDMI) Validation Matrix

Type of Validity	Characteristics	CDMI Validation	Expected Result Metric
Face	Evaluation by untrained individual on how good an item or group appears	Evaluation by students that used the CDMI	Scale Responses Recommendations Improvements
Content	Review by experts of an item or group of items	Review of the CDMI by expert industry professional / faculty reviewed	Scale Responses Recommendations Improvements
Criterion	Measurement of the instrument correlation with other instruments	Compare Modified Rational Experiential Inventory (REI) Rational/Experiential to the CDMI –How? Identify other instruments to compare in the future	Statistical Analysis Recommendations Improvements
Construct	Meaningfulness of the instrument over multiple uses	Deploy CDMI in multiple setting to evaluate in the future	Experiential Comments Improvements

Each independent research project will be unique and will provide additional insights to improve the quality of CDMI with the ultimate goal of having a tool with high level of validity to measure decision making process within construction industry. Figure 4 presents the CDMI validation plan delineating the anticipated validity projects with their focus, publication and expected execution timeframes as well as the improvement to the CDMI. The plan also includes a simple coding system with four digits for each project. The first two digits correspond to the research partner, the third digit corresponds to the validation type/focus and the fourth digit corresponds to the project number. For example: "P3A1" corresponds to a research project with partner 3 "P3" that focuses on face validity "A" and it is the first project with this partner "1". Additionally, the figure shows that multiple projects can be done with the same partners as highlighted in yellow.

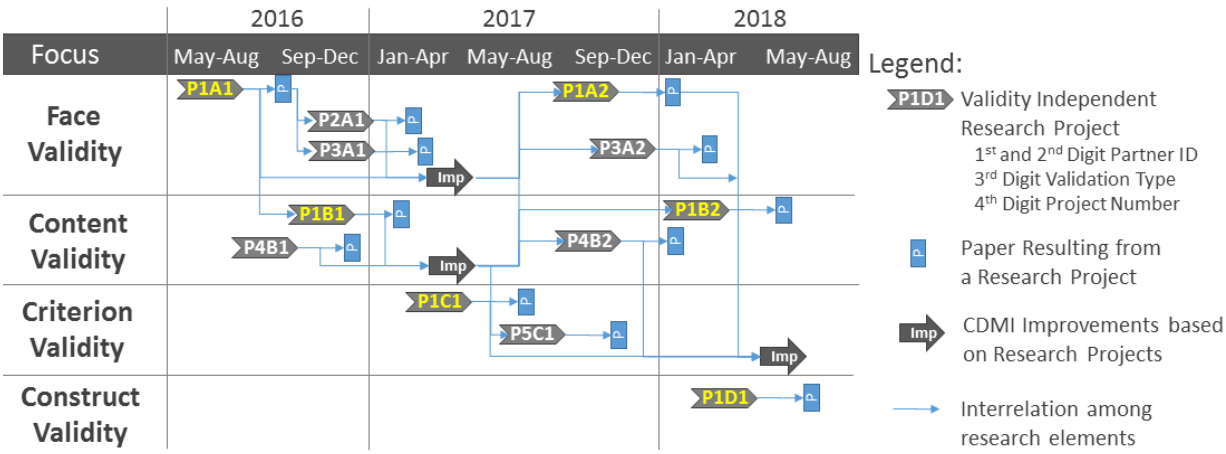

Figure 4 CDMI Validation Plan

3.2 CDMI Reliability Evaluation

Reliability is the consistency of a measuring instrument in yielding a certain result when the entity being measured remains unchanged (Leedy & Ormrod, 2015). No instrument is perfect, so errors are expected to occur during any measurement process (Litwin, 1995); nevertheless, reliability is the overall consistency of a measure. A measure is said to have a high reliability if it produces similar results under consistent conditions (M, 2016); the more consistent the survey results, the higher the reliability (as shown in figure 5).

Lower Reliability Vs Higher Reliability

Figure 5 Schematic concept of reliability

3.2.1 Assessment of Reliability

There is a rich literature addressing methodologies to evaluate the reliability of survey instruments. The most frequently presented for research studies include (Leedy & Ormrod, 2015):

1. Inter/Intra-rater reliability: Inter-rater reliability assesses the degree of agreement between two or more raters in their appraisals. It is the extent to which two or more individuals evaluating the same product or performance give identical judgments (Leedy & Ormrod, 2015). Intra-rater reliability, on the other hand, refers to a single individual's consistency of measurement over different rounds of evaluation (Fink, 1995).
2. Internal consistency reliability is the extent to which all the items within a single instrument yield similar results (Leedy & Ormrod, 2015). It assesses the consistency of results across items within an instrument. It analyzes how consistent the results are for different items for the same construct within the measure (Trochim, 2006). There are multiple measures to evaluate internal consistency, including: Average Inter-Item Correlation, Average Item-total Correlation, Split-Hal Reliability, and Cronbach's Alpha, among others.
3. Equivalent forms reliability is the extent to which two different version of the same instrument yield similar results (Leedy & Ormrod, 2015).
4. Test-retest/Stability reliability assesses the degree to which survey scores are consistent from one survey administration to the next. Measurements are gathered from a single rater who uses the same method(s) or instrument(s) and the same surveying conditions. The consistency can be determined with a correlation coefficient such as the Pearson's correlation coefficient.

In short, reliability has to do with the quality of measurement. In its everyday sense, reliability is the "consistency" or "repeatability" of measurements (Trochim, 2006) and can be estimated in multiple ways depending on the reliability type. Similar to the validity, testing a survey instrument's reliability is more like hypothesis testing rather than a calculation (Litwin, 1995). Thus, again more than one type of measure is recommended to evaluate reliability of the instrument.

3.2.2 Methodology to Assess Reliability the CDMI

It is important to determine the CDMI's reliability to ensure the quality of its result in measuring decision making within the construction industry. The reliability assessment methods that will be mainly used are: Internal and Stability. Each reliability evaluation will be analyzed individually; also multiple rounds of reliability evaluation will be consolidated to perform additional analysis. Results from the reliability evaluations will contribute to the improvement of the CDMI. Similar to the validity test, evaluation of reliability will have a recursive nature and after applying each improvement to the CDMI, the improved CDMI's reliability will be re-evaluated again as suggested by Figure 6.

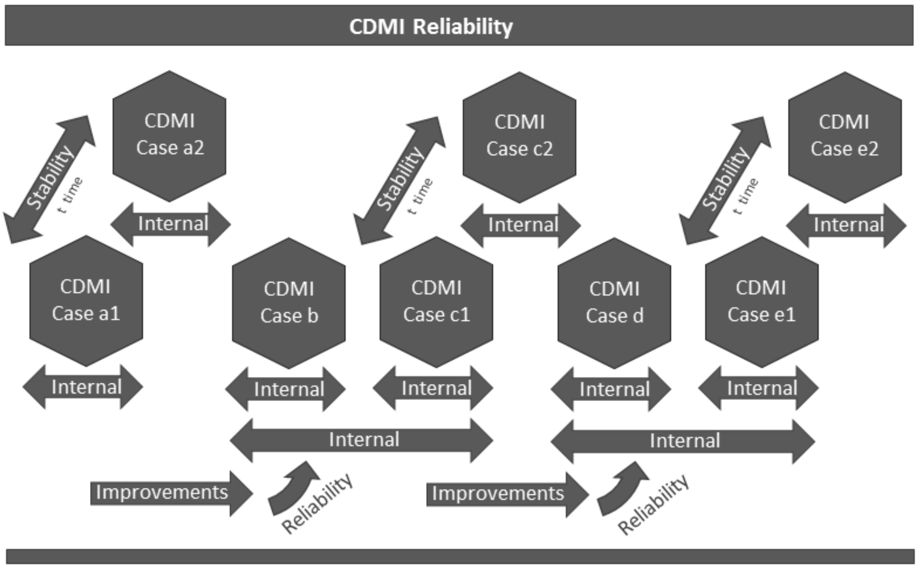

Figure 6 CDMI Reliability Methodology

Each reliability evaluation will be performed through a series of independent, but inter-related research projects. Each research project will follow a quantitative descriptive methodology. The quantitative descriptive methodology will be used because reliability will be determined mainly using correlation calculations. As previously indicated, this methodology does not change or modify the situation under investigation (in this case the reliability of the CDMI).

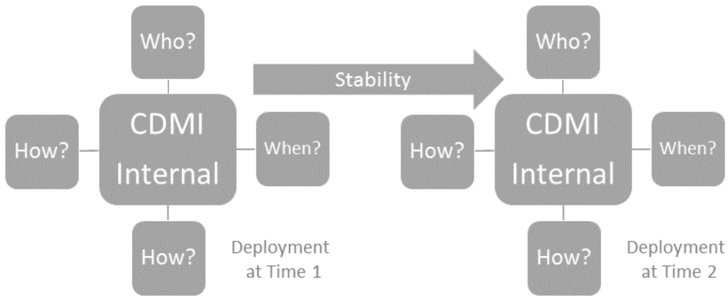

Figure 7 CDMI Reliability Instrument

For the internal consistency reliability, the participants will be provided with the CDMI instrument. The CDMI instrument's main purpose will be to collect information about the participants' What? When? How? and Who? of the construction decision making process as shown in Figure 7. For the stability reliability, the same CDMI instrument will be provided to the same participants twice with a lag of 2 weeks to 2 months in between the two evaluations.

Similar to the validity assessment, the number of participants, demographic characteristics and reliability protocol, will vary among independent research projects, depending on the partnering researcher and the type of reliability to be used. It is expected that each research project will have between 15 and 60 participants as they are most likely to take place in academic institutions, The data for research projects will be collected electronically using an on-line survey system and will be stored in a centralized database. Descriptive statistics will be used to analyze the stored data.

Table 4 presents a synopsis of the four types of reliability measures with their corresponding characteristics, CDMI reliability implementation and the expected result metrics. Additionally, Figure 8 presents the CDMI reliability plan delineating the anticipated reliability projects with their focus, publication and expected execution timeframes as well as the improvement to the CDMI. Each project is designated with a simple coding system composed of four digits. The first two digits correspond to the research partner, the third digit corresponds to the reliability type/focus and the fourth digit corresponds to the project number. For example: "P3E1" corresponds to a research project with partner 3 "P3" that focuses on internal reliability "E" and it is the first project with this partner "1". The "P1E1" project is expected to be finished by the middle of the Fall 2016 while the "P1E2" project is expected to be completed by the end of the Fall 2016.

Table 4 Construction Decision Making Inventory (CDMI) Reliability Matrix

Type of Reliability	Characteristics	CDMI Reliability	Expected Result Metric
Inter/Intra-rater	Consistency among one or more evaluator	Does not apply CDMI is an online instrument that is consistently delivered without an evaluator	---
Internal	Similarity of items' results within the instrument	Comparison of internal questions	Statistical Analysis
Equivalent	Similarity of results of two different version of the instrument	Does not apply. CDMI older version will be discarded and unique fine-tune versions will be implemented	---
Stability	Consistency of results of two evaluations of the same participant	Comparison of repeated evaluations	Statistical Analysis

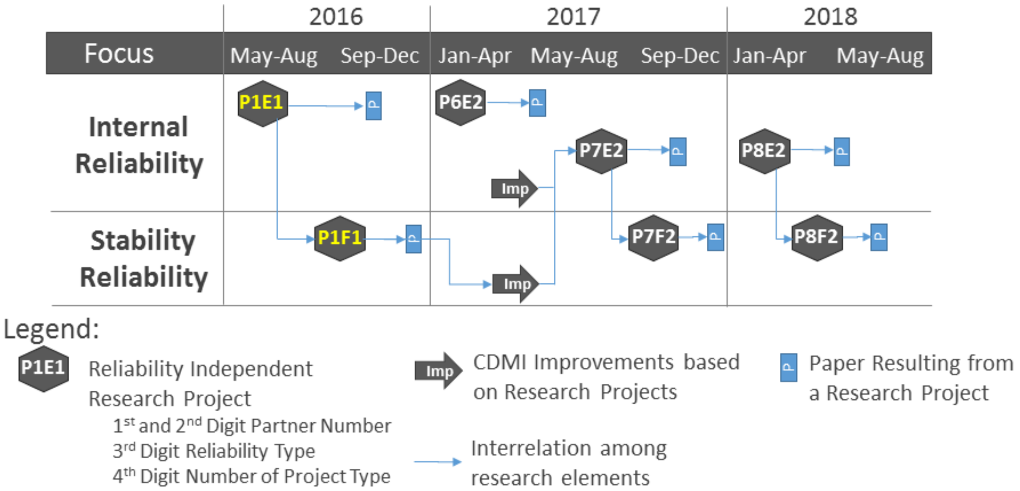

Figure 8 CDMI Reliability Evaluation Plan

4 Discussion and Conclusion

Assessment of validity and reliability for CDMI, based on the schema explained above, has already been started with two parallel studies. These two studies engaged student samples from two post-secondary construction programs in North America. The two institutions are: 1- The School of Construction at the University of Southern Mississippi (USM), Hattiesburg, Mississippi, United States, and 2- The Angelo DelZotto School of Construction Management at George Brown College (GBC), Toronto, Ontario, Canada. The students participating in the study had backgrounds in architectural, construction engineering/management, and civil engineering; at different levels of undergraduate and postgraduate degrees. Table 5 shows the discipline distribution of students in the two institutions participating in the two rounds of the CDMI deployment. CDMI was deployed twice in each institution to be able to perform not only the internal reliability but also stability reliability evaluation.

The students in the sample from CGB were participating in a post graduate Building Information Modeling (BIM) license program, bringing together a spectrum of experience; from recently graduated engineers/architects to experienced professionals with years of background in Architecture/Engineering/Construction (AEC). The students in the sample from USM were participating in two programs: Construction Engineering Technology and Architecture Engineering Technology.

Table 5 Frequency Distribution of Participants by Major, Institution and Run

	Group				
	First Run at USM	Second Run at USM	First Run at GBC	Second Run at GBC	**Total**
Not Answered	0	2	2	0	**4**
Construction	20	8	8	6	**42**
Architecture	6	2	12	13	**33**
Other	1	0	1	0	**2**
Total	**27**	**12**	**23**	**19**	**81**

Figure 9 illustrates additional demographic information about the sample of participants in the first phase of assessment studies. The information about the participants is organized in the figure by the two major disciplines (construction and architectural).

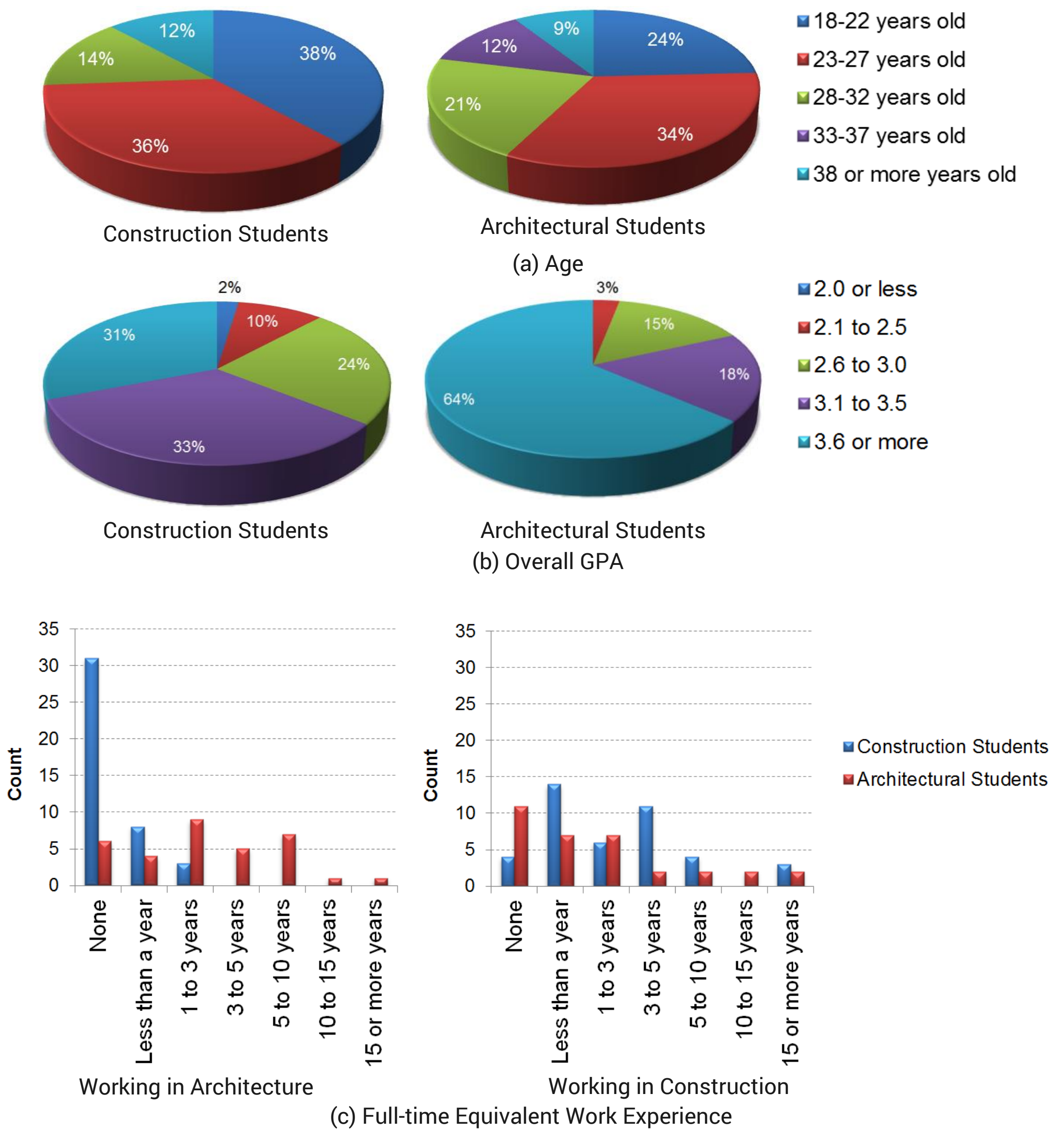

Figure 9 Demographic information of participants in assessment study of CDMI

Apart from this population, three students with other backgrounds were among the participants, which are not shown in Figure 9. As seen, participants are representatives of a wide range of ages (from 18 to 40 years old and even beyond – Figure 9-a). 23-27 years old was the mode for both disciplines. The GPA of architect students was higher than construction students as shown in Figure 9-b. It is worth noting that while some of the architect students had construction work experience the majority of the construction students had no architect work experience. Furthermore, in order to normalize the amount of students' professional experience, they are all calculated on a full-time annual basis, with an assumption of 2000 hours being equivalent to one year of full time experience (Figure 9-c).

The two groups of tests (reliability and validity) were performed using the participant samples. Internal and Stability reliability, as well as face validity were tested through various rounds of the study at USM and GBC. Each run of the test was well distanced in time with respect to the previous one. Students were asked to use the same computer platform to complete the test survey in different rounds, so that the system identifies them based upon their IP address. Details of those tests and their results are elaborated and discussed elsewhere (due to space limitations in this paper). However, based on the two parallel studies, the following are some initial general findings to possibly improve the CDMI assessment framework for validity and reliability:

- Add to the CDMI a module that performs the calculations (of the What? When? How? and Who?) immediately after the participants finish answering the questions. This can create an instantaneous incentive for the participants who could lead to increase in the quality and quantity of responses. This module would provide participants with a tangible outcome (for example, learning what form of decision maker they are, how their decision making behavior can be compared versus others, etc.)
- Include additional questions to identify participants for possible longitudinal analysis. This would eliminate the costs and requirements of having to accommodate students in a computer lab, with each student having to use the same computer (the same IP address) over different rounds. This will also make it easier for researchers who get involved in the study to not being concerned with these logistical constraints ahead of time.
- Apart from students, right incentives must be created for the faculty members who get involved in the study. Understanding the differences among various groups/cohorts of students or their behavior in different course subjects may be among other such incentives.
- Clearly communicate to the participants the ultimate goals and objectives of the study (perhaps by creating a short video – up 30 seconds long) to increase participants engagement prior to taking the CDMI and to. This might reduce the tendency of participants to memorize their responses to re-use in the future cycles of the test.

For the future rounds of the test, expansion in two directions is of interest; first, adding to the size of the sample, through involving more institutions all around the world to incorporate international experiences and balance out the effect of different sources of bias. This can also help to entertain a more pluralist view on the nature of decision making in construction and reach a collective intelligence by harnessing wisdom of the crowds. Second, to continue working on the validity evaluation by covering content validity, criterion validity and construct validity. These will require collaboration and contribution from other academic institutions as well as engaging expert industry professionals (as explained earlier).

References

Alhumaidi, H. M. (2015). Construction contractors ranking method using multiple decision makers and multiattribute fuzzy weighted average. Journal of Construction Engineering & Management, 141.

Bruijn, H. d., & Heuvelhof , E. t. (2000). Networks and decision making. Utrecht: LEMMA Publishers.

Brualdi, A. (1999). Traditional and Modern Concepts of Validity. Retrieved from http://files.eric.ed.gov/fulltext/ED435714.pdf

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

Fink, A. (1995). The Survey Handbook (1st ed.). Thousand Oaks, California: Sage Publications.

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.

Hatush, Z., & Skitmore, M. (1998). Contractor selection using multicriteria utility theory: an additive model. Building & Environment, 33(2-3), 105-115.

Heravi, G., & Faeghi, S. (2014). Group decision making for stochastic optimization of time, cost and quality in construction projects. Journal of Computing in Civil Engineering, 28(2), 275-283.

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.

Leedy, P. D., & Ormrod, J. E. (2015). Practical Research: Planning and Design (11th Edition). Upper Saddle River, New Jersey: Pearson

Lesniak, A., & Plebankiewicz, E. (2015). Modeling the decision-making process concerning participation in construction bidding. Journal of Management in Engineering, 31(2).

Linstone, H. A. (1984). Multiple perspectives for decision making (bridging the gap between analysis and action). New-York: North-Holland.

Litwin, M. (1995). How to Measure Survey Reliability and Validity (1 edition). Thousand Oaks, California, 91320: SAGE Publications, Inc.

Lu, Q., Won, J., & Cheng, J. C. (2016). A financial decision making framework for construciton projects based on 5D Building Information Modeling (BIM). International Journal of Project Management, 34, 3-21.

Luoma, J. (2016). Model-based organizational decision making: a behavioral lens. European Journal of Operation Research, 249, 816-826.

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.

Mora, M. (2011). Validity and Reliability in Surveys. Retrieved from http://www.relevantinsights.com/validity-and-reliability#sthash.rFO7cTRV.3

Mukherjee, A., m, & uga, H. (2009). A decision-making framework to assess stakeholder value in adoption of sustainable practices in construction. Construction Research Congress (pp. 548-557). Seattle, Washington, United States : ASCE.

Palaneeswaran, E., & Kumaraswamy, M. (2001). Recent advances and proposed improvements in contractor prequalification methodologies. Building & Environment, 36(1), 73-87.

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

Parkin, J. (1996). Organizational decision making and the project manager. International Journal of Project Management, Vol. 14, No. 5, 257-263.

Rosenzweig, P. (2014). The benefits and limits of decision models. McKinsey Quarterly.

Tang, P., ulherjee, A., & Onder, N. (2010). Studying dynamic decision making in construction management using adaptive interactive simulations. Constructin Research Congress (pp. 379-388). Banff, Alberta, Canada: ASCE.

Topcu, Y. (2004). A decision model proposal for construction contractor selection in Turkey. Building & Environment, 39, 469-481.

Trochim, W. M. K. (2006). Research Methods Knowledge Base. Retrieved from http://www.socialresearchmethods.net

Williams, Y. (n.d.). Face Validity: Definition & Examples. Retrieved from http://study.com/academy/lesson/face-validity-definition-examples.html

Williams, Y. (n.d.). Construct Validity in Psychology: Definition & Examples. Retrieved from http://study.com/academy/lesson/construct-validity-in-psychology-definition-examples-quiz.html