Introducing Organizational Intelligence to the Construction Industry

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The construction industry, which is inherently multidisciplinary, has adopted intellectual and technical business improvements from many other industries with the intent to optimize productivity. Therefore, there is a need to implement new managerial strategies that incorporate standardized and structured repeatable procedures. As part of the effort to establish a better understanding of management from organizational resources through final construction, this paper introduces a new theoretical approach for Organization Intelligence in Construction (OIC) that is based on the procedural ability of an organization to efficiently process, support, measure, and reason through management issues. Organizational intelligence is applied in all organizations to enhance the understanding of managerial processes and assets/resources within the organization. The measured performance of a managerial process depends on the capability and quality of resources that are available within the organization and/or the acquisition and management of resources that are outside of the organization. This paper suggests a mechanism to standardize construction processes by identifying the role of relationships in an organization's operation and the organizational cognitive abilities that subsequently determine the effective and efficient use of resources to aid in successfully completing an operation. A case example provides the foundation for a replicable template that reveals how construction processes, personal and organizational knowledge, skills, and resources contribute to managerial activity functions.

Key Words: Business Organizational Intelligence, Cognitive Ability

Introduction

Although there is no widely accepted definition for Organizational Intelligence (OI) the authors' content that Organizational Intelligence can be defined, measured, and used to successfully achieve performance improvement when applied to complex tasks. OI can be characterized by the incorporation of various aspects of individual human intelligence, corporate knowledge management, and decision support systems, as well as business strategy and its deployment across functions and organization levels. To set the reader at ease in understanding this rather new concept several baseline definitions are needed. From an OI perspective, the adjective 'intelligence' represents the possession of high levels of enabling mental ability that allows an entity, e.g., a construction organization, to comprehend ideas and to rationally and quickly process relevant information. Intelligence was first applied to humans, and the measuring of supposed differences in intelligence became the task of science. In the study of organizations, a theory of intelligence has been applied to many areas including artificial intelligence, machine intelligence, and business intelligence. This has been done to establish a meaningful understanding of the intellectual capabilities of non-human systems.

The term "ability" can be used to characterize or designate individual human attributes such as a musical or athletic ability. The human attribute of cognitive ability is generally concerned with all levels of human task management. A task is defined as any activity that an individual may engage in (or be made to engage in) in order to achieve a specifiable class of terminal states of affairs (Carroll 1993). Thus, intelligent humans use their abilities to successfully perform tasks, while intelligent organizations use their abilities to successfully perform organizational tasks including the art and science of construction management.

However, it is difficult to determine the assigning and measuring of OI because there is no standard definition and its treatment in the literature includes different capabilities in different studies (Jung, 2009). Traditional measures of cost and time are used to measure individual productivity or organizational performance and thus are often cast as

representing OI, but in reality organizational activities are interdependent through project based collaborative activities, not individual achievements. Thus to measure the intelligence of an organization's collaborative activities a far more sophisticated approach is needed. To enhance the level of intelligence within complex organizations, a way to define established and reliable measuring criteria for each organizational activity, other than simply cost and time, is necessary. Although many technical improvements support efficient performance of organizational activities, organizational activities, by nature, are an extension of human activities, and these improvements ultimately support human activities. Therefore, applying principles from the study of human intelligence offers a promising approach to resolving the problem of dealing with the complexity of organizational activities.

As one example of moving the theoretical basis of OI forward, this paper investigates the use of organizational intelligence in construction processes as a means to identify appropriate management standards for managing these processes. As a first step in addressing this particular example of Organizational Intelligence in Construction (OIC) an exploration of how intelligence is embodied within the construction organization's processes, resources, and assets is required. This current manuscript effort is to present a common interface between cognitive mapping of humans and organizations and the synthesis of the two. It is hoped that other construction researchers can gain new insights from this alone. The authors recognize that value generation isn't derived from this relationship alone but must rely on more sophisticated tools (not being presented in this manuscript), such as 1) a focus on systems standardization (a more extensive use of flow mapping then discussed herein), 2) the establishment of operational standardization as a baseline (briefly introduced within this manuscript), 3) recognizes latent variables that correspond to performance factors and attributes, some inherent, some acquired, and 4) uses an intelligibility learning model (ILM), not presented in this paper, to gauge managerial task needs and appropriate resource response to these needs.

Relevance of Organizational Intelligence in Construction

In general, all sectors of the construction industry share a common ground in their approach to increasing productivity or performance. However, to simplify understanding the discussion has been limited to addressing current improvements in construction processes or the adoption of new technologies only, with no consideration of the resources or assets that are already available within the organization. The management of construction processes is usually assumed to consist of several fundamental components, such as personnel, system, function, application, object, etc, not all of which apply to every process. Although a construction project may be a success, the construction organization typically does not create explicit knowledge from its intangible assets for use in subsequent projects. Moreover, the success of a project is highly dependent on successful interface management among project players. A working structure must specifically address intellectual abilities and how to manage, maintain, and grow intelligence within an organization's typical managerial processes. Therefore, standardizing internal construction processes in terms of procedural activity is likely to reveal fundamental factors that are manageable, as well as building an improved knowledge base for the construction organization and by extension the industry.

Structurally a construction project typically involves many actors and requires efficient managerial leadership among them. In addition to Information/Communication Technology (ICT) as a performance enhancer there are many other theories/tools for applying intelligence to enhance performance, including Total Quality Management (TQM) and Knowledge Management (KM). The construction companies involved in a project will be of different sizes and abilities, but every construction organization must routinely perform managerial processes, regardless of their size or ability. However, the intelligent applications, expected to contribute to performance improvements, e.g., Building Information Modeling (BIM), are not typically customized to suit different organizations' requirements. Additionally, it is questionable how many construction companies can afford to use or invest in Industry Foundation Classes (IFCs), aecXML schemas, or other silver bullet solutions related specifically to enhancing project managerial process. Although several studies have investigated the effectiveness of using IT tools (Williamson and Woo, 2003; Rivard et al., 2004), there is currently no standard method for measuring changes in organizational performance resulting from information technology and associated managerial strategy usage. In other words, the intelligent applications needed to enhance project performance often overlook routine processes using fundamental components.

To date, individual intelligent applications applicable to the construction industry have been studied in isolation and hence few if any effects due to combining multiple applications have not been identified. It is clear that a critical methodology is required to analyze an organization's status and to identify specifically which intelligent application assets, e.g., BIM, or other internal and/or external organizational assets are beneficial to a specific organization. If the organization fails to take into account organizational differentiations and the applicability of intelligent application, it may lose its ability to effectively manage and control projects. Thus, research to adapt Organizational Intelligence for the management of intelligent assets to suit specific construction industry needs, namely Organizational Intelligence in Construction (OIC) as proposed here, is urgently needed to establish a working practice that reveals an organization's nature, its assets, and its fundamental components.

Construction Activity and Intelligence

Defining OIC requires a careful examination and characterization of the organization and its main structures and needs. For the purposes of general discussion, the organization will be characterized in terms of its managerial activities through human/tool interactions within an organization knowledge domain. Organizational activities like human activities are dynamic organisms that adapt to change, evolve to respond to higher levels of functioning, and make decisions. Human functions that manifest intelligent activity within the organization are a form of OI. In other words, all functional activities, especially information processing by personnel within the organization use cognitive abilities supported by organizational resources.

Therefore, any activities within the organization that rely on a specialized cognitive ability to support organizational tasks can be described in terms of human cognitive abilities. For example, if a student is to solve a math problem, they require a minimum of four cognitive abilities to perform the action: 1) long-term storage & retrieval, 2) processing speed, 3) quantitative knowledge, and 4) reading/writing ability, (see figure 1). These abilities describe a human's cerebral activity for a particular activity. If this student is allowed to use a calculator, the cognitive ability "quantitative knowledge" will be de-emphasized. The analog of this within an organizational activity is to treat the calculator as a technological improvement, and thus a professional will require additional knowledge and skills such as education and training to use the technological improvement, i.e., the calculator. Once this additional education has been provided and the new skills mastered, the professional will use less human cognitive ability while improving their performance. Ultimately, human quantitative capabilities can be supported or replaced by a technological improvement, in this case a calculator.

Figure 1: The characterization of math solving human activity in terms of cognitive abilities

In the same way that cognitive abilities are used to characterize human processes, a particular process within an organization can be explained in terms of cognitive abilities, as shown in Figure 2. In the instance of a construction estimator performing a quantity takeoff and cost estimate, the professional, at a minimum, makes use of the following organizational cognitive abilities: 1) Working Memory & Retrieval, 2) Processing Speed, 3) Quantitative Knowledge, and 4) Reading/Writing/Recording Ability. The success of the takeoff and estimate is not only dependent on the professional's ability, but also how well the organization supplies and supports the necessary organizational cognitive abilities.

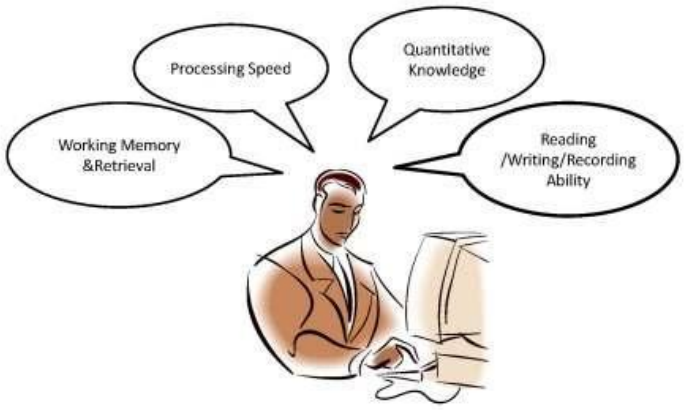

Figure 2: The characterization of construction estimating activity with cognitive abilities

This representative characterization, shown in figure 2, provides an example of how one may precisely and effectively describe an organizational process and hence determine which particular abilities will be required for a particular task within the managerial process, in this instance estimating. Additionally by characterizing organizational activities using a cognitive ability mapping suggests areas for improvement or technical enhancements that can result in improved performance through additional education or asset acquisitions. As human cognitive ability concerns all levels of human tasks (Flanagan et al., 2000), organizational cognitive ability involves organizational tasks and can be addressed by specific aspects of organizational intelligence. To derive organizational intelligence from the learning of human intelligence, this paper posits the following hypotheses:

- Organizational cognitive ability governs and characterizes organizational activity
- An organization provides organizational cognitive ability
- The satisfaction of organizational cognitive ability for organizational activities manifests as organizational intelligence

Standardization of a Construction Management Process

Although many construction management tasks are relatively complex, they can often be analyzed by separating them into discrete processes, stages, or components. In general, a process refers to any action or series of actions by means of which something is operated upon to produce some result (Carroll, 1993). An understanding of construction activities, especially managerial processes, is therefore essential in order to specify the resources/assets that are necessary for achieving higher levels of organizational performance. The analysis of these activities into discrete processes facilitates the comprehension and judgment that particularize the resources needed to process a specific task. The procedural analysis of two typical construction managerial processes, namely a Request for Information (RFI) and a material submittal, are shown in figure 3. The analysis reveals that tasks #4 (Recording/Transmitting) and #5 (Receiving/Recording) in both analyses are performed repeatedly by the construction professional as part of the managerial processes. Such findings of repeated activities throughout the procedural analysis provide an indication of areas where organizational resources can be effectively and efficiently applied.

To develop the new model for Organizational Intelligence in Construction, an illustrative case based study approach was adopted to collect and present detailed information about particular participants, especially those engaged in managerial activities in construction. In this example it is applied to construction managerial processes and encompasses the procedural ability of a construction organization to efficiently process, support, measure, and reason through management issues in terms of organizational intelligence in construction. Prior to suggesting a technical improvement with additional education requirements it is essential to precisely and effectively standardizing the internal organizational process as the first step in determining which organizational cognitive abilities are required for a particular task.

Construction Activity Viewed From a Cognitive Ability Perspective

The development of organizational cognitive ability can illuminate procedural activities in the organization and determine the effective utilization of resources. There are, however, limitations on human cognitive capacity while performing administrative functions (Simon, 1945), and thus to achieve higher performance other organizational resources can assist and replace human activities in these various organizational tasks. Hence, for some tasks technical improvements can replace human activity. The initial step in formulating the new Management of Organizational Intelligence (OI) theory is, therefore, to develop a model for organizational cognitive ability that can then be used to map organizational cognitive ability to the managerial process for characterization.

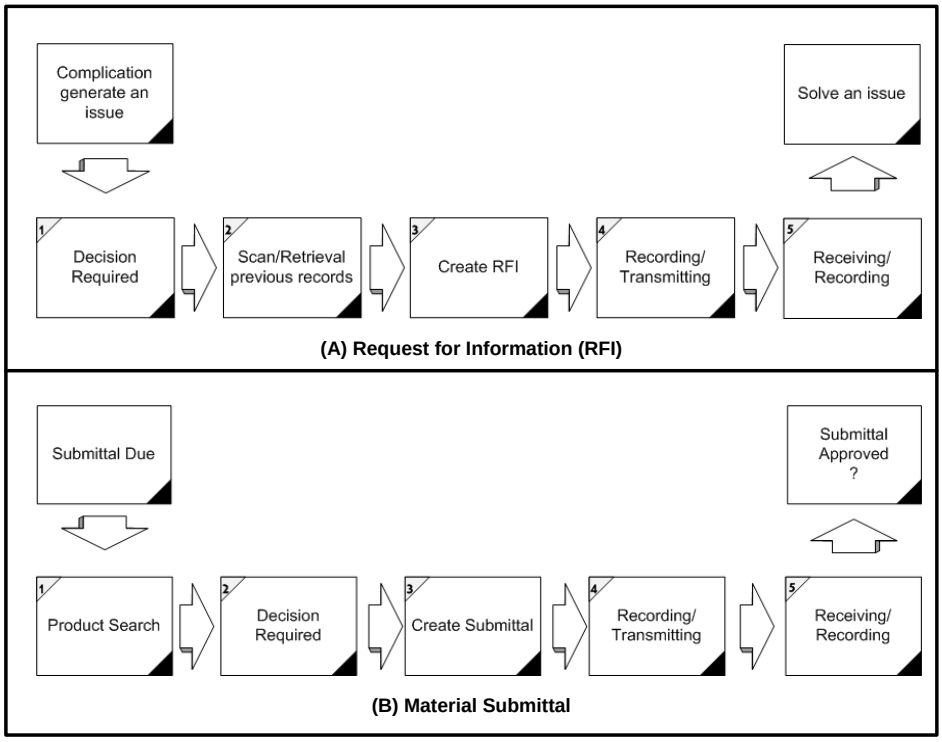

Figure 3: Two examples of procedural analysis for standardization

The performance of any organizational task requires both knowledge and ability, with most tasks requiring knowledge from multiple sources and integrative abilities. For instance, the successful information processing of a construction RFI (see figure 3) will depend on at least three organizational cognitive abilities: 1) Processing Speed; 2) Reading/Writing/Recording Ability; and 3) Visual Processing. RFIs are widely used and are no longer merely a communication tool but have become an important means of preventing defective design (Zack, 1999). In this construction management example Visual Processing may identify and correct a drawing defect, Reading/Writing/Recording Ability can accurately describe the issue and prevent duplication, and Processing Speed can prevent unnecessary delays. This cognitive characterization of each procedural activity can result in a new approach to dealing with the analytical knowledge that determines mutual interrelationship from organizational resources and activities and further improves performance, as shown by the inclusion of these cognitive abilities within figure 4.

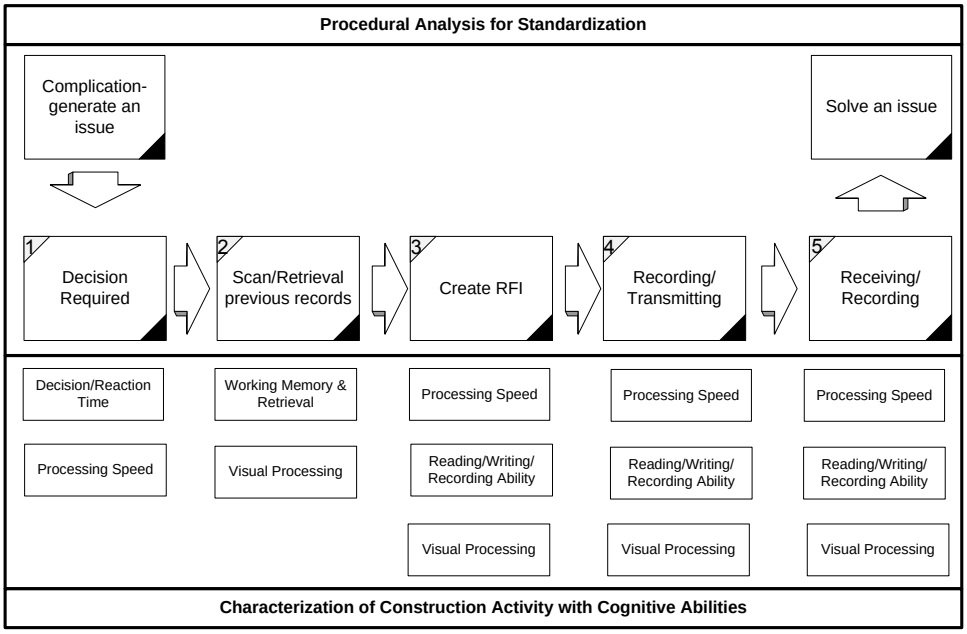

Figure 4: Initial development for characterization of an RFI construction managerial activity

A Working Definition of Organizational Cognitive Abilities

Using Flanagan et al. (2000) human cognitive abilities as a model one can state that within an organizational context, "[the six organizational] cognitive abilities represent basic typical and longstanding characteristics of [organizational] intelligence that govern or influence a great variety of functional tasks in a given [organizational] processes." In this new model, the parallels between human cognitive ability and organizational cognitive ability consist of six abilities: (1) Decision/Reaction Time, (2) Processing Speed , (3) Quantitative Knowledge , (4) Reading/Writing/Recording Ability , (5) Visual Processing , and (6) Working Memory and Retrieval , all of which are modeled on human cognitive abilities. As noted previously processing an RFI will require the uses of organizational cognitive abilities #1, 2, 4, 5, and 6. Human cognitive ability is a gift that is a basic part of human nature; it is a constitutional and longstanding characteristic and is concerned with all levels of human tasks (Carroll, 1993). Psychologists consider cognitive ability to be made up of two distinct elements: fluid intelligence and crystallized intelligence. Fluid intelligence describes the reasoning behind the decision to do something, and crystallized intelligence is the ability to retrieve necessary knowledge from memory.

In organizing an analytical knowledge model for OIC, the human cognitive abilities of Short-term Memory and Long-term Storage and Retrieval were combined to form the new organizational cognitive ability of Working Memory and Retrieval. Managerial processes are planned activities within defined phases and so are not dependent on Short-term Memory. Human Auditory Processing was been incorporated into Reading/Writing/Recoding Ability because, not withstanding listening, active organizational task activities generally do not include auditory processing.

For this research a set of six organizational cognitive abilities, previously undocumented in the literature, were developed. These provide a mutually exclusive and collectively exhaustive set of cognitive abilities for OI applicable to many organizations including the construction industry. A detailed definition of these six organizational cognitive abilities is as follows:

1. **Decision/Reaction Time** reflects how quickly the organization reacts and makes decisions. It reflects the immediacy with which an organization addresses problems and selects from among a range of alternative solutions. This is a qualitative response that is related to Processing Speed in organizational activities.

2. **Processing Speed** is the ability to perform tasks fluently, including uncommon tasks, to maintain focused collaboration. Faster processing speed is more efficient because it improves the power of the Working Memory and Retrieval and Decision/Reaction Time.

3. **Quantitative Knowledge** represents the organization's capacity to acquire quantitative, analytical, and procedural knowledge and then solve quantitative organization activities and problems, including numeric calculations such as accounting, estimating, scheduling, and resource allocation.

4. **Reading/Writing/Recording Ability** is the basis upon which the organization acquires and exchanges information in unified formats, both within the organization's own structural hierarchy and with outside organizations. It encompasses all the available material in both the field and the office, including items such as field reports, daily logs, submittals, and so on.

5. **Visual Processing** denotes the organization's ability to acquire, generate, analyze, synthesize, store, retrieve, transform, and deliver visual objects or pattern images, and form and store images such as graphical charts, digital photos, visualizations, and animations.

6. **Working Memory and Retrieval** is the ability to apprehend, hold, store, and fluently retrieve new or previously acquired information such as change orders, daily reports, and drawings. Personnel must be able to update, modify, store, and later retrieve documents from the organization's database at need.

These six organizational cognitive abilities parallel and emulated, beyond the basic level of fluid intelligence and crystallized intelligence, the ten recognized human cognitive abilities. Cognitive ability in an organization is represented by the ability to perform a sequential task and is created by organizational activities. As discussed and demonstrated throughout this paper its intent is to present the interface between cognitive mapping of humans and organizational resources and their synthesis for the ability to gauge managerial task needs and to subsequently guide applying appropriate resources in response to these needs.

Conclusions

This paper prefaces the beginnings of a theoretical foundation for better understanding of how human cognitive ability can be mapped to organizational cognition. The development of a new theoretical approach to comparing and examining current organizational practices and processes for the optimal use of organizational resources during organizational activities, especially managerial processes, particularly within the construction industry is presented by the use of procedural mapping and cognitive interfaces linked to organizational resources. There are many examples of management functions where human cognitive abilities that concern tasks and flow management activities within an organization have been replaced or supported by technological innovations; for instance, spreadsheets in estimating replaced with preformatted estimating software.

However, the benefit of technological innovations that enable estimating software to deliver better productivity and performance to meet organizational needs is sometimes doubtful. The performance of an organizational activity involves typical and longstanding characteristics that can be considered as an organizational cognitive ability. This organizational cognitive ability functions by deploying appropriate organizational assets or resources to accomplish the activity and how well it does so can be measured in terms of the level of integration between organizational cognitive ability and the resources provided for a particular task. For instance mapping organizational cognitive abilities to support the estimating function can assist an organization in understanding their needs and thus aide in satisfying those needs with the resulting action being a transformation of estimating from using calculators and pads, to one that employs spreadsheets, to an even higher level of one that uses commercial estimating software, and then into an organization that acquires BIM to support the estimating function.

By integrating the concept of organizational cognitive ability into performance measurement, a method can be implemented that 1) clarifies the level of support provided by organizational resources to support a particular activity, 2) provides a measure of six different organizational cognitive areas that quantify the product of organizational resources integrated within organizational activities, and 3) can provide an organizational processes IQ score similar to a human IQ score. Additionally, the mapping of organizational cognitive abilities with

organizational activities can help an organization learn important abilities needed to perform a particular construction process efficiently and effectively. Another area of application is that the same cognitive mapping processes can be applied to an organization's training curriculum development and enhancement.

The study of human intelligence targets the measurement of cognitive abilities in a specific activity (verbal of spatial cognition), the standardization of construction processes identifies the organization's operation relationships through organizational cognitive abilities. This can aide in determining an organization's targeting of fundamental acquisitions and/or substitutions of technical improvements for human activity to achieve higher levels of performance. This new concept of Organizational Intelligence in Construction as presented in this paper establishes the first steps in ascribing organizational cognitive abilities to construction management work processes. It can subsequently offer additional comprehensive information to assist decision makers seeking to optimize organizational and task specific performance when seeking solutions regarding the adoption of alternative business solutions and/or technological innovations.

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