Identifying Multilevel Metrics for Construction Competency and Performance Measures

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ABSTRACT

Construction competencies are combinations of skills, knowledge, technologies, other resources, and practices of a construction organization that contribute to increased effectiveness, competitiveness, profitability, and performance. Previous studies have developed mechanisms to identify and develop construction competencies that aid in performance measurement at project and organization levels, separately. In reality, construction organizations are project-based organizations with complex interactions between competencies influencing performance at different levels. The challenges associated with multilevel construction competency measures include identifying the interrelationship between competencies at different levels and relating multilevel competencies to multilevel performance measures. To address these challenges, this paper provides a review of the literature related to multilevel construction competency frameworks and performance measurement methods. Based on an analysis of the literature, a multilevel framework is developed and presented for construction competency and performance measures. Finally, a data collection approach is provided that will assist researchers and industry practitioners in evaluating construction competencies and performance.

INTRODUCTION

The environment in which the construction industry operates is becoming more complex as a result of increasing uncertainties in technology, budgets, and development processes. Over the past two decades, the productivity of the construction industry has averaged only 1% growth per year, whereas a rate of 2.8% growth occurred in the case of the total economy and 3.6% in manufacturing (Barbosa et al. 2017). Moreover, the percentage of productive work in a typical construction project ranges between 30 and 40%, resulting in the frequent failure of delivering construction projects on time and on budget (Hanna et al. 2016).

Recent studies placed strong emphasis on the importance of construction organizations adopting effective strategies and performance measurement methods to improve the competitiveness of the construction industry (Eken et al. 2020; Hanna et al. 2016; Loufrani-Fedida and Saglietto 2016; Omar and Fayek 2016; Tiruneh and Fayek 2019). Successful identification, understanding, and management of construction competencies and their effects on performance is critical for construction organizations to forecast their performance, recognize competencies that require improvement, and develop performance enhancement strategies. Furthermore, studies have developed mechanisms to identify and develop construction competencies that aid in performance measurement at the project (Omar 2015) and organization (Eken et al. 2020; Tiruneh and Fayek 2018) levels separately.

In reality, construction is a complex system with numerous interactions between competencies at different levels, influencing overall construction performance. While competency and performance measures have been developed at both project and organizational levels, competencies have not yet been linked to each other and then mapped to performance at multiple levels. Indeed, several authors have pointed out the need for simultaneous development of multiple levels of competencies (Frame 1999; Loufrani-Fedida and Saglietto 2016), stating that if an organization focuses on only one level, it will be unable to achieve the desired performance results. According to Hobday (2000), construction organizations can be classified as project-based organizations (PBOs) in which "the project is the primary business mechanism for coordinating and integrating all the main business functions of the organizations" (Hobday 2000, p. 874). In PBOs, the competencies are built up through the execution of major projects, and it is important to establish a holistic insight of both project and organizational levels of competencies (Loufrani-Fedida and Missonier 2015). The challenges associated with multilevel construction competency and performance measures are mainly: (1) identifying the interrelationship between competencies at project and organizational levels and (2) relating these multilevel competencies to construction performance measures at project and organizational levels.

In this paper, a comprehensive set of project- and organization-level competency and performance measures are summarized and updated from existing literature. In addition, a multilevel competency framework is proposed that will enable researchers to identify the link between project- and organization-level competency and performance measures, which will in turn provide construction organizations with an improved means of predicting performance. This paper is organized into five sections. The first section provides an introduction and states the problem statement of the paper. The second section offers a review of previous studies on construction competencies and performance at the project and organizational levels. The third section includes a discussion on the proposed multilevel framework. The fourth section presents measurement methods for construction competency and performance criteria and a data collection approach. The last section presents conclusions and reflections on future research to be conducted towards developing a predictive multilevel construction competency and performance model.

CONSTRUCTION COMPETENCY AND PERFORMANCE MEASURES

Competency Management in Construction. In the last three decades, competency management has become an increasingly popular focus of study because of its influence on an organization's performance and efficiency (Loufrani-Fedida and Saglietto 2016). Having clearly defined competencies allows organizations and their employees to know exactly what is expected of them and how they should accomplish their tasks. Competency can be defined as the ability of an individual, a team, or a company to mobilize and combine resources (knowledge, skills, and attitudes) in order to implement an activity or a given process (Frame 1999; Dainty et al. 2004; Krajcovicova et al. 2012; PMI 2017). Competency management is the set of managerial actions taken by an organization to identify, construct, and develop competency models using one of the two modes of learning referred to as *exploitation* and *exploration* (Loufrani-Fedida and Saglietto 2016).

A competency model is a collection and specific combination of knowledge, skills, abilities, and other characteristics (KSAOs) needed for effective performance in the execution of a task (Campion et al. 2011; Krajcovicova et al. 2012). Campion et al. (2011) identified individual KSAOs or combinations of KSAOs as competencies, and the set of competencies as the competency model. Competency models can be developed for specific jobs, job groups,

organizations, occupations, or industries. Krajcovicova et al. (2012) stressed that the development of competency models depends primarily on a company's intentions and direction. According to Campion et al. (2011), competency models can help organizations align their initiatives to their overall business strategy.

Performance Measurement in Construction. In the last three decades, competency management has become an increasingly popular focus of The literature reveals three specific types of performance measures used in the construction industry: key performance indicators (KPIs); key performance outcomes (KPOs); and perception measures (PerMs) (Tiruneh and Fayek 2018). KPIs are indicative of assigned processes and can predict future trends, which aids in identifying problems at the early stages of a project. KPIs are considered leading measures in that they provide opportunities for change. In contrast, KPOs are results of completed actions or processes; they are lagging measures and do not enable change. Managers in construction sometimes utilize KPOs as KPIs, such as profit, return on equity, and time, though they may be unaware of it (Barlas 1996). Perception measures (PerMs) can be either lagging or leading, depending on when surveys and interviews are conducted relative to completed actions or processes, and they are dependent on the managers' focus (IEEE 1990).

Competency-based Performance Measurement Models. Competency-based multidimensional conceptual models have been proposed to predict the performance of project managers (Dainty et al. 2004). Examples include the project manager competency development framework (PMCDF) model (PMI 2017), international competence baseline (ICB) model (IPMA 2006), and global standard for project management competences (GSPMC) model (Vukomanović et al. 2016). These conceptual models are generic, so they do not capture industry and organizational contexts. At the individual level, Poveda and Fayek (2009) developed a fuzzy expert system performance evaluation model that has the capacity to predict and evaluate the performance of construction trade foremen. Similarly, Rezk et al. (2019) developed a competency evaluation model for trade workers in transportation projects for a state highway agency. Studies by Cheng et al. (2007) and Omar and Fayek (2016) suggested that construction organizations must develop competency and performance models at the project level. Cheng et al. (2007) defined project competence as an organization's ability to skillfully generate/select and execute projects and identified performance measurements for final project outcomes. Omar and Fayek (2016) developed a fuzzy neural network (FNN) to model project competency and performance. Tiruneh and Fayek (2018) developed an adaptive-network-based fuzzy inference system (ANFIS) model for evaluating organizational competency and predicting organizational performance. FNNs offer the learning capabilities of artificial neural networks (ANNs) while maintaining the flexibility in variable description of fuzzy-based modeling.

However, because of the diversity, dynamism, and complexity of construction organizations and their projects, the current success of different competency and performance modeling approaches is difficult to measure. Furthermore, the relationships between individual, activity, project, and organizational competencies and performance have not been established. An integrated framework is needed that will provide a well-defined and structured hierarchy of levels of competencies that coexist in construction organizations and model the interrelationships between competencies and their impact on performance at multiple levels in construction organizations (Loufrani-Fedida and Missonier 2015). This framework does not exist in the literature, which is a significant gap for researchers and managers seeking to improve understanding of competency and performance management in PBOs (Loufrani-Fedida and Saglietto 2016).

PROPOSED FRAMEWORK FOR MUTILEVEL CONSTRUCTION COMPENCY AND PERFOMANCE

Multilevel Construction Competency and Performance Framework. In PBOs, project execution is the major business endeavor, and the effectiveness of competency and performance management in project execution affects the development of new opportunities (Loufrani-Fedida and Saglietto 2016). As a PBO, a construction organization is recognized as a learning organization, because it requires comparisons and coordination between project competencies and allows competency development through the execution of tasks and major projects (Hobday 2000). In addition, organizational competency is considered as a key factor for project effectiveness (i.e., achieving schedule, cost, and quality objectives). In accordance with PBO characteristics, this paper proposes a framework that allows both competencies and performance to develop through project execution. The proposed integrated framework, as shown in Figure 1, provides a hierarchical link between competencies at the project and organization levels of assessment, is developed specifically for the construction context, and maps the multilevel competencies to the hierarchy of project- and organization-level performance measures.

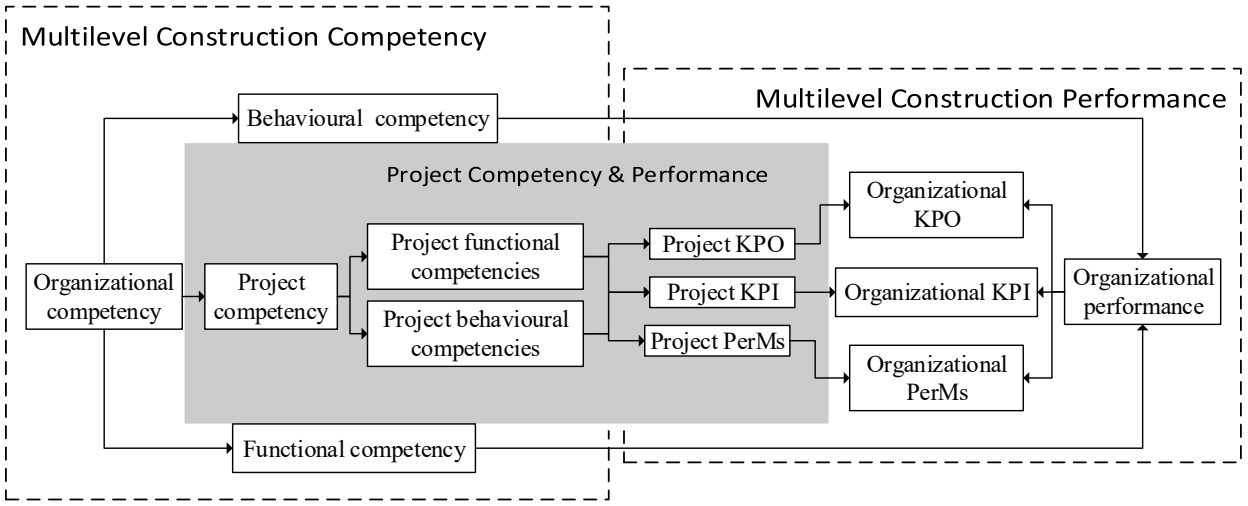

Figure 1. Proposed multilevel construction competency and performance framework.

The proposed framework addressed the major challenge associated with developing a multilevel construction competency and performance measure, by defining hierarchies of construction competencies and performance measures at project and organization levels; identifying how competencies at each level will be integrated into a multilevel competency model; and relating the multilevel model of competencies to performance at each level of assessment. Hence, the proposed framework permits holistic competency measurement as well as performance evaluation and prediction. It can be seen as a two-way relationship, where organizational competencies drive, orient, and support one or multiple projects' competency and performance, and in turn organizational performance is continuously redefined through the unique execution and practices of projects.

Construction Competency Measures. According to Campion et al. (2011), competencies can be hierarchically arranged, meaning they can be divided into categories and subcategories. A hierarchical structure can often organize competencies and simplify their presentation for the user,

especially if there are a large number of competencies (Campion et al. 2011). The existing body of knowledge provides a foundation for construction competencies identification and categorization (Campion et al. 2011; Omar and Fayek 2016; IPMA 2006; Tiruneh and Fayek 2018; Loufrani-Fedida and Missonier 2015; Loufrani-Fedida and Saglietto 2016). IPMA (2006) classifies competency into three major categories: technical (project management tasks), behavioral (individual characters), and contextual (knowledge and capabilities). Similarly, Omar and Fayek (2016) categorize competencies into two groups: functional (how an organization operates and functions) and behavioral (attributed to individuals). Based on past literature, competency measures necessary for determining construction competencies are summarized, categorized, and presented in Table 1. Competencies at both the organizational and project levels are identified and categorized into two sets, as functional and behavioral competencies. Functional competencies are related to how an organization or project operates and functions, and behavioral competencies refer to attributes of individuals working at the project or organizational level. The proposed framework relates project competencies (i.e., behavioral and functional) as a core subcategory of an organizational competency, as shown in Figure 1.

Table 1. Construction competency measures.

Organizational Behavioral Competency	
Category	Competency Measures
Core organizational	Achievement drive/oriented, Adaptability/flexibility, Building trust, Competitive, Culture and values, Innovation, Risk taking
Top management	Strategic thinking/planning/policy, Analytical ability, Initiative, Leadership, Judgment
Individual/ personal	Commitment, Creativity, Enthusiasm, Motivation, Reliability/dependability, Sales mind set / selling skills, Self-confidence, Self-regulation/control, Sensitivity
Project behavioral competency	Analytical ability, Training, Assessment ability, Decision making, Leadership, Teamwork, Consultation, Motivation, Negotiation and crisis resolution, Ethics, Self-control, Reliability, Problem solving, Commitment, Adaptability, Building trust, Interpersonal skills, Influence/assertiveness, Cultural competence, Initiative, Integrity/high standards, Responsiveness, Reasoning
Organizational Functional Competency	
Category	Competency Measures
General administration	Goal-orientation, Human resources, Manage/support diversity, Talent (staff) development/training, Team orientation / team work
Cross-functional	Communication skill/management, Cooperation/cooperativeness, Customer support, Customer value/focus, Delegation, Internal cooperation and coordination, Public and governmental relations, Stakeholder focus/responsiveness
Technical	Attention to detail, Business acumen / business management skills, Commitment to safety, Creativity, Critical and analytical thinking, Finance management, Marketing, Planning and organizing, Problem solving, Prevention & decision making, Technical knowledge / job knowledge

Production/ operational	Construction technology / integration management, Manufacturing and construction, Material management, Operations and maintenance, Process engineering/management, Product engineering
Engineering R&D	Business, Legal and public policy, Construction law and regulation, MIS/computer IT, New product/technology development
Managerial/ supervisory	Engagement (people, organizations, partners), Management excellence, Resource management, Values and ethics
Project functional competency	Project change management, Project commissioning and startup, Project communication management, Project contract administration, Project cost management, Project engineering and procurement management, Project environmental management, Project human resource management, Project innovation, Project integration management, Project quality management, Project resource management, Project risk management, Project safety management, Project scope management, Project stakeholders management, Project team building, Project technology integration, Project time management, Project workface planning, Project workforce development

Construction Performance Measures. Key performance indicators (KPIs), key performance outcomes (KPOs), and perception measures (PerMs) are identified at both the project and organization levels from existing literature.

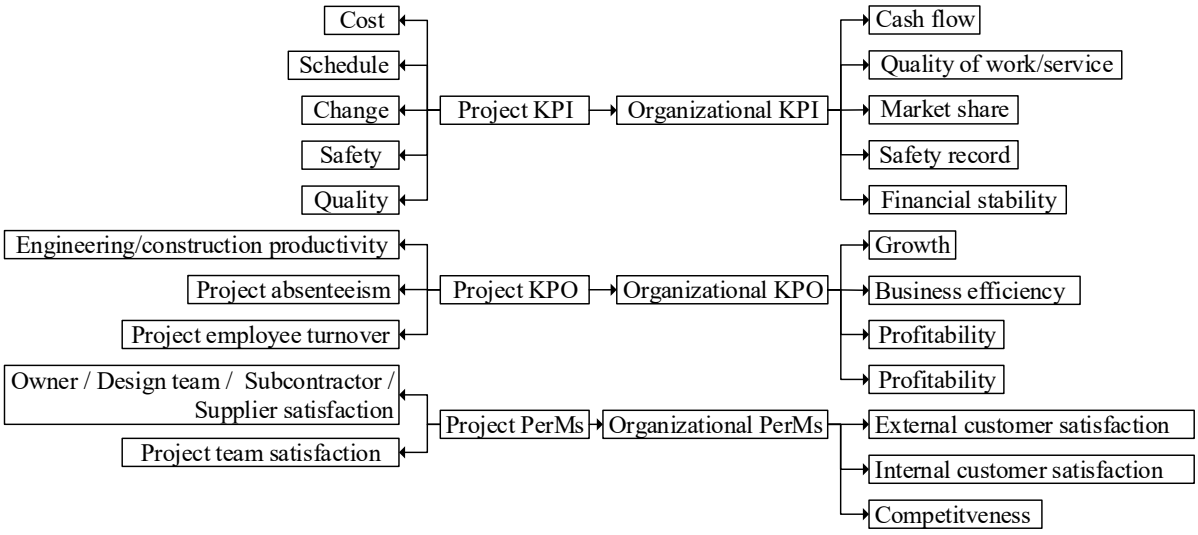

Figure 2. Construction performance measures.

The selection of KPOs, KPIs, and PerMs is based on review of their application in past research in the construction domain (Campion et al. 2011; Omar and Fayek 2016; Tiruneh and Fayek 2018; Loufrani-Fedida and Missonier 2015; Loufrani-Fedida and Saglietto 2016). At the organizational level, detailed performance measures categorized under KPOs, KPIs, and PerMs are linked to project-level performance measures, as shown in Figure 2.

METHODS OF MEASURING MUTILEVEL CONSTRUCTION COMPETECIES AND PERFOMACES

The proposed framework includes both competency and performance measures, which are further divided into sets of evaluation criteria that can be captured through different construction experts

and collected from construction organizations and their projects either quantitatively or qualitatively. Qualitative measures have uncertainties attributed to subjective judgement, linguistic expression, numerical approximations, and imprecise measurements. Hence, qualitative measures used to characterize competencies and performance are measured using linguistic terms, and quantitative measures are measured numerically. For measuring evaluation criteria of functional competencies at project and organizational levels, two types of scales are identified. The first scale is a five-point maturity scale (levels 1–5) that measures project and organizational maturity, focusing on practices and processes to assess the presence of different evaluation criteria (Omar 2015; Omar and Fayek 2016). The second scale is a seven-point importance rating scale (levels 1–7) to identify the importance and relative weight of each evaluation criterion.

Table 2 gives sample functional competency criteria for engineering research and development category at an organizational level. The maturity levels are scaled as follows: (1) Informal – use of a practice is ad hoc or inconsistent for each project and organizational unit; (2) Documented – disciplined processes exist for each individual project and the organization; (3) Integrated – defined processes exist across the each individual project and the organization; (4) Strategic – quantitatively managed process control exists across the each individual project and the organization; and (5) Optimized – continuous process improvement exists across each individual project and the organization. The importance rating scale is ordered as follows: (1) Extremely Unimportant, (2) Unimportant, (3) Slightly Unimportant, (4) Neither Important nor Unimportant, (5) Slightly Important, (6) Important, and (7) Extremely Important.

Table 2. Sample engineering R&D (functional) competencies measurement scale.

Competency Evaluation Criteria	Maturity Scale (1–5)					Importance Scale (1–7)						
1. New technology development												
1.1 Continuous development of staff to cope with new technologies and products developed	1	2	3	4	5	1	2	3	4	5	6	7

Similarly, Omar and Fayek (2016) and Tiruneh and Fayek (2018) used two sets of seven-point bipolar measurement scales for behavioral competencies, measuring agreement and importance. The agreement rating scale is ordered as follows: (1) Strongly Disagree, (2) Disagree, (3) Somewhat Disagree, (4) Neither Agree nor Disagree, (5) Somewhat Agree, (6) Agree, and (7) Strongly Agree. This scale is used to measure the extent to which respondents agree that the different evaluation criteria for behavioral competencies exist within an organization (Omar 2015). Table 3 gives sample behavioral competency criteria for the decision-making category at the project level.

Furthermore, numerical scales are assigned to measure quantitative performance measures. For example, profitability and growth can be assigned percentage points on a numerical scale. Qualitative performance measures, such as company image / reputation under competitiveness, can be measured using predetermined rating scales. In general, qualitative performance measures include subjective PerMs (e.g., satisfaction, competitiveness) and some measures under KPIs (e.g., quality of service, market returns). Satisfaction rating scales are ordered as follows: (1) Very Dissatisfied, (2) Dissatisfied, (3) Neither Satisfied nor Dissatisfied, (4) Satisfied, and (5) Very Satisfied. Table 4 shows measurement scales for construction competencies and performance.

Table 3. Sample decision-making (behavioural) competencies measurement scale.

Competency Evaluation Criteria	Agreement Scale (1–7)
1. Decision Making	
1.1 Members of this team collaborate before making important decisions.	1 2 3 4 5 6 7

Table 4. Measurement scales for construction performance measures.

Category	Example of Measures	Data Type	Scale of Measure
KPI	Cash flow, Rework factor, and Market share	Quantitative	Number, Percentage
	quality of service, and market returns	Qualitative	Satisfaction (1–5) rating scale (perception metrics)
KPO	Profitability and Growth rate	Quantitative	Number, Percentage
PerMs	Company image/reputation, satisfaction and competitiveness	Qualitative	Satisfaction (1–5) rating scale (perception metrics)

CONCLUSIONS AND FUTURE RESEARCH

This paper provides a review of literature related to multilevel construction competencies, competency management, and competency-based performance models in construction and nonconstruction PBOs. A multilevel construction competency and performance framework is proposed to address a significant gap in the literature, linking competencies at the project and organizational levels and mapping these multilevel competencies to construction performance measures at both levels. The framework enables researchers to identify the link between project- and organization-level competency and performance measures, which in turn can provide construction organizations with an improved means of predicting construction performance. This study also categorizes and summarizes a comprehensive list of functional and behavioral competency measures and performance measures (KPIs, KPOs, and PerMs) for use in the proposed framework. Finally, this paper proposes a data collection approach for measuring construction competencies and performance.

This study was part of a larger, ongoing research project developing a novel integrated framework and fuzzy hybrid multilevel modeling environment to allow construction organizations to assess and improve competencies at multiple levels and to predict their impact on performance. Future work will involve development of a more advanced application of the proposed framework with a model using hybrid fuzzy system dynamics (FSD) and fuzzy agent-based modeling (FABM) to analyze multilevel construction competencies and predict performance. Furthermore, practical cases studies will be used to demonstrate the applicability of the framework. The advanced model will combine the capability of fuzzy logic for capturing the subjective uncertainties in construction with the dynamic and complex modeling capacity of system dynamics and agent-based modeling approaches. The multilevel competency model will be developed using the FSD approach to capture cause-and-effect relationships between project competencies and performance measures. In addition, the FSD project competency and performance model will be integrated as an agent in an FABM organizational competency and performance model, to develop a construction performance predictive model.

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