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ABSTRACT

Investigation of the performance of engineering project organizations is critical for understanding and eliminating inefficiencies in today's dynamic global markets. The existing theoretical frameworks consider project organizations as monolithic systems and attribute the performance of project organizations to the characteristics of the constituents. However, project organizations consist of complex interdependent networks of agents, information, and resources whose interactions give rise to emergent properties that affect the overall performance of project organizations. Yet, our understanding of the emergent properties in project organizations and their impact on project performance is rather limited. This limitation is one of the major barriers towards creation of integrated theories of performance assessment in project organizations. The objective of this paper is to investigate the emergent properties that affect the ability of project organization to cope with uncertainty. Based on the theories of complex systems, we propose and test a novel framework in which the likelihood of performance variations in project organizations could be investigated based on the environment of uncertainty (i.e., static complexity, dynamic complexity, and external source of disruption) as well as the emergent properties (i.e., absorptive capacity, adaptive capacity, and restorative capacity) of project organizations. The existence and significance of different dimensions of the environment of uncertainty and emergent properties in the proposed framework are tested based on the analysis of the information collected from interviews with senior project managers in the construction industry. The outcomes of this study provide a novel theoretical lens for proactive bottom-up investigation of performance in project organizations at the interface of emergent properties and uncertainty.

INTRODUCTION

Over the past five decades, different theoretical frameworks related to project management have been created to facilitate a better understanding of performance assessment in engineering project organizations. Existing theoretical frameworks related to performance assessment and management (so called "PM 1.0") are rooted in a reductionism perspective towards project organizations. In this reductionism perspective, complex engineering projects are investigated as monolithic systems and the performance of project organizations is attributed to the

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characteristics of individual constituent or process. This traditional approach to management of engineering project organizations fails to address the requirements of modern engineering projects. The limitations in the existing methodologies have led to the creation of new tools and techniques towards a new bottom-up approach to project management (so-called “PM 2.0”) (Levitt, 2011). In contrast to PM 1.0, the PM 2.0 approach facilitates conceptualizing project organizations as system-of-systems (SoS) consisting of networks of autonomous agents, resources and information (Zhu and Mostafavi, 2014).

Investigation of project organizations as SoS requires investigation of new dimensions of analysis that have not been investigated in the traditional PM 1.0 approach. One of these new dimensions is related to investigation of *emergent properties* in performance assessment of project organizations. According to the theories of complex systems and the theory of integrative levels, emergent properties are attributes of complex systems that arise from the interactions between the constituents, and are more than the sum of properties of the individual constituent (Sage and Cuppan, 2010). The objective of this paper is to create and test a framework for performance assessment in project organizations based on the investigation of emergent properties. While there are various emergent properties in project organizations, our focus in this paper is on the emergent properties that affect the ability of project organizations to cope with uncertainty. In the following sections, we first discuss the gaps in the existing knowledge pertaining to performance assessment in project organizations. Then, we propose a novel framework for assessment of performance in project organizations based on the investigation of the *emergent properties* and the *environment of uncertainty*. Finally, we test the existence and significance of different dimensions of the environment of uncertainty and emergent properties in the proposed framework based on a qualitative comparative analysis of the information collected from interviews with senior project managers in the construction industry.

BACKGROUND

Performance assessment has been investigated in different streams of research related to project management body of knowledge as well as the organizational theory. In one stream of research, which is rooted in the traditional PM 1.0 approach to project management, different studies investigated the performance of project organizations based on the attributes of the individual process and factor. For instance, the literature on construction project management has attributed the performance of projects to different factors such as: the quality of site management, experience of contractors, as well as leadership of project managers (Chan and Kumaraswamy, 1996; Iyer and Jha, 2005). The main limitations of the studies related to this stream of research are their *descriptive, deterministic*, and *one-size-fits-all* nature. The existing studies are mainly descriptive rather than prescriptive. The attributes of the processes and factors can explain why a project succeeded. However, they cannot be used for organizing projects to ensure successful outcomes. In addition, the difference related to the level of complexity and uncertainty in projects has not been considered. From the perspective of this stream of research, a project with certain attributes can succeed regardless of the existing levels of complexity and uncertainty.

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Such one-size-fits-all approach has failed to explain the performance inefficiencies in projects with different levels of complexity and uncertainty. Finally, the studies related to this stream of research have failed to investigate the *integrative attributes* that arise as a result of the interactions between different processes and factors.

In another stream of research, researchers have investigated the impacts of the complexity and uncertainty related to the external and internal environment in which a project organization operates. Wite (1988) asserts that good management of project organizations can contribute towards project success, but it is unlikely to be able to prevent project failure. Different studies have investigated the impacts of project environment on the ultimate performance outcomes. Examples of factors related to the environment of projects affecting the performance outcomes include: project complexity (e.g., project size and technical challenges), natural disasters (e.g., hurricane and flood) and economic environment (e.g., inflation and recession) (Mahamid, 2013; Ahzahar et al., 2011). The main limitation of the studies related to this stream of research is the lack of consideration of the way project organizations interact with the environment. The individual and integrative attributes of project organizations affect the ability of project organizations to cope with the changes in the environment. In addition, the descriptive nature of these studies does not provide any insight on how to design project organizations which are capable of successfully operating in uncertain environments.

The literature on contingency theory is another stream of research investigating the performance of project organizations. Contingency theory provides a new perspective to understand and assess organizational performance based on the principle that “all possible ways of organizing are not equally effective”, and “organizations that exhibit structures that fit the demands of their environment will be more successful than organizations that do not” (Pfeffer, 1982). The contingency view of organizations includes both the macro and micro dimensions (Mealiea and Lee, 1979). In the macro level, congruence should be achieved at the interface of the environmental requirement (e.g., size and technology) and the organizational structure. At the micro level, the impact of the congruence between the organizational structure and the individual micro behaviors on the organizational performance are considered. One of the distinctive examples related to the implementation of contingency theory in investigation of project organizations is Virtual Design Team (VDT) studied by Levitt and his research team over the past two decades. VDT is a computational model of project organizations which investigates emergent organizational performance through simulation of micro-level actions and interactions among the actors in the organization (Jin and Levitt, 1996). Early versions of VDT (i.e., VDT-1 and VDT-2) modeled the performance of project organizations containing actors with perfectly congruent goals engaged in complex but routine engineering design work within static organization structures. VDT-3 incorporated activity flexibility, complexity, uncertainty and interdependence into the model. It also considered the effects of goal incongruence between agents on their information processing and communication behaviors (Levitt et al., 1999). More advanced versions of VDT tools (i.e., VDT-4 and VDT-5) have further extended the capability to include non-routine work and the consideration of speed and accuracy of information processing

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by agents (Levitt, 2012). The development of VDT tools facilitated the consideration of dynamic behaviors (e.g. information processing and decision making) of autonomous human agents, and the effects of these micro behaviors on the macro-level organizational performance. This distinctive approach breaks the “one size fits all” convention in organizational design and management, and bridges between cognitive and social psychological micro-organization theory and sociological and economic macro-organization theory for project teams. While contingency theory has addressed some of the limitations of the other streams of research pertaining to performance assessment in project organizations, it does not investigate the *integrative attributes* that arise as a result of the interactions between different project constituents. These integrative attributes are referred to as “emergent properties” in the theory of complex systems. Emergent properties are integrative traits of complex systems-of-systems that arise from micro-behaviors and interactions of individual constituent. Investigation of emergent properties is critical in better understanding of the overall macro patterns in complex project organizations.

The significance of emergent properties has recently been recognized in the organizational theory. Recent studies in the area of organizational research have sought new theories pertaining to the performance of organizations based on the investigation of the emergent properties. For example, resilience, which is the capacity of a system to absorb and recover from disturbance, is evaluated as one of the most significant factors for the success of an organization (Hamel and Välikangas, 2003). Organizational resilience has been investigated in different industries and systems (Zhu and Ruth, 2013; Francis and Bekera, 2014). Other emergent properties closely related to resilience, such as flexibility, agility and recoverability, also have been investigated in the context of organizational theory (Phillips and Wright, 2009; Shu and Zong, 2012). Another significant emergent property investigated in organizational research is vulnerability. Organizational vulnerability is defined as inadequate adaptive capacity in organizations to cope with uncertain conditions (Liu et al., 2011). Different studies have investigated strategies for assessment and mitigation of vulnerability in various complex systems (Berle et al., 2011; Hellström, 2007). Despite these studies, our understanding of the emergent properties in project organizations is rather limited.

POINT OF DEPARTURE

The review of the literature presented in the previous section highlights the evolution of the existing theories towards an integrated approach to performance assessment in project organizations in which the success or failure of a project is contingent on: (i) the level of complexity and uncertainty in which a project organization operates, (ii) the attributes and micro-behaviors of project constituents, and (iii) the emergent properties of project organizations affecting their ability to cope with the environment. However, to the best of our knowledge, a framework that facilitates such integrated investigation of performance in project organizations is missing in the existing literature. Hence, the objective is to propose and test an integrated framework for performance assessment in project organizations at the interface of the emergent properties and the environment of uncertainty. Specifically in this paper, we aim at identifying

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different dimensions of emergent properties affecting the ability of project organizations to cope with uncertainty as well as the dimensions of environment of uncertainty in which a project operates. Based on this objective, we seek to answer the following research questions:

1. What are the emergent properties affecting the ability of project organizations to cope with uncertainty?
2. What properties can best capture the environment of uncertainty in which a project organization operates?

INTEGRATED FRAMEWORK FOR PROJECT PERFORMANCE ASSESSMENT

An integrated framework for project performance assessment is proposed in this paper at the interface of emergent properties and uncertainty. Dimensions of emergent properties in project organizations and dimensions of project environment of uncertainty are explained in this section.

Dimensions of Project Organization Emergent Properties

There are different emergent properties identified in the literature related to complex systems. Resilience, vulnerability, agility, adaptive capacity, absorptive capacity, flexibility, and recoverability are examples of emergent properties considered both in the complex systems and organizational theory literature. The definitions have shown overlaps across different categories of emergent properties. For example, Liu et al. (2011) defines organizational vulnerability as inadequate adaptive capacity in organizations to cope with uncertain conditions. Hollnagel et al. (2006) defines resilience as the ability to sense, recognize, adapt and absorb variations, changes, disturbances, disruptions and surprises.

A typology that captures the ability of project organizations to cope with uncertainty is missing in the existing literature. According to Meredith (1993), creation of typology is one of the key methods of conceptualization. Doty and Glick (1994) made a distinction between typology and classification and emphasized that typologies enable achievement of elegant descriptions to explain complex processes that determine specific outcomes. We used the criteria suggested by (Scott, 1981) in creation of a typology for conceptualizing emergent properties in project organizations: *intuitively sensible, mutually exclusive, and collectively exhaustive*. Based on these criteria, we investigated the emergent properties that could represent the ability of project organizations to cope with uncertainty. Three dimensions of project organization emergent properties have been identified: *absorptive capacity*, *adaptive capacity*, and *restorative capacity*. Francis and Bekera (2014) define these three emergent properties as the *resilience triangle*. Our hypothesis is that the ability to cope with uncertainty in project organizations can be determined by locating a project organization in the space formed by these three dimensions of emergent properties. The definitions of these emergent properties are provided in the following sections.

Absorptive Capacity

Absorptive capacity is defined as the ability of a project organization to resist uncertainty-induced perturbations or seize opportunities without changing its initial stable governance

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structure and execution processes (Francis and Bekera, 2014; Vugrin et al., 2011). The ability is often achieved through enhancement of robustness and redundancy in the processes and constituents of project organizations.

Adaptive Capacity

Adaptive capacity refers to the project organization's ability to adjust itself in terms of organizational structure or execution processes in response to undesirable disruption or desirable opportunity in order to maintain or enhance the performance outcomes (Francis and Bekera, 2014). For example, having a "Plan B" is a common strategy for project management under uncertainty. The capability of an organization to adopt a "Plan B" when necessary is critical for the success in projects. Since project organizations consist of interconnected networks of different interdependent sub-systems, adjustment in any single constituent will affect other constituents in the networks. Thus, the speed and ease for adaptation are closely related to effective communication and mutual decision making based on interdependencies across different levels of project organization.

Restorative Capacity

Restorative capacity, also can be called as recoverability of a project organization is related to its ability to minimize the consequences caused by uncertainty-induced perturbations and rapidly recover (Francis and Bekera, 2014; Shu and Zong, 2012). When absorptive capacity and adaptive capacity are not effective to cope with the undesirable effects of uncertainty-induced perturbation, projects experience organizational dysfunction and performance deviation. Restorative capacity is the ability for project organizations to quickly recover from these situations and return to regular operational performance.

Dimensions of Project Environment of Uncertainty

A successful project is the one in which the project organization has the ability to cope with the uncertain scenarios imposed by the internal and external project environment. Excessive ability to cope with uncertainty is not efficient while insufficient ability to cope with uncertainty can be detrimental. According to the contingency theory, the fitness between the emergent properties of the project organization and the project environment of uncertainty leads to different performance outcomes. Different studies have investigated the uncertainty in project organizations from different perspectives. Souder et al. (1998) evaluate the environment of uncertainty related to project organizations from two aspects: technical uncertainty and market uncertainty. Hong et al. (2004) consider the uncertain project environment as external and internal difficulties associated with achieving the project objectives. In this study, the concept of project environment of uncertainty is derived from the perspective proposed by Perminova et al. (2008), in which uncertainty is define as "a context for risk as events having a negative impact on the project's outcomes, or opportunities as events that have beneficial impacts on project performance".

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When using system thinking to analyze complex project organizations, researchers have found that complexity is a significant indicator for the level of uncertainty in a project. Suh (1999) has defined complexity as a measure of internal uncertainty in achieving a set of specific functional requirements. Different studies have investigated frameworks for assessment of complexity in project organizations (EIMaraghy et al., 2012; Lessard et al., 2013; Bosch-Rekveldt, 2011). While complexity is usually related to internal uncertainty arising from the system itself, there are also external sources of uncertainty from a larger context (e.g. natural, social and political) which could significantly affect project performance outcomes. Based on the previous studies, we hypothesize that the project environment of uncertainty can be captured using three dimensions: *static complexity*, *dynamic complexity*, and *external source of disruption*.

Static Complexity

Static complexity is time-independent complexity that is affected by the structure of a system (EIMaraghy et al., 2012). Static complexity can be understood from ontological and teleological aspects pertaining to “what the project system is” (Vidal et al., 2011). Static complexity in project organizations is mainly related to the structural features of the project (e.g., project type, project size, project location, and technology used in the project) (Vidal et al., 2011). Static complexity of a system increases the possibility for unknown situation. Thus, a greater static complexity usually indicates a higher level of uncertainty in project environment.

Dynamic Complexity

Dynamic complexity is time-dependent and deals with the operational behaviors of the system (EIMaraghy et al., 2012). Different from static complexity, dynamic complexity is more related to “what the project system does” and “how the project system evolves” (Vidal et al., 2011). The drivers of dynamic complexity include human-related operation, material flow, as well as module reliability and failure (EIMaraghy et al., 2012; Serdarasan, 2013). The level of dynamic complexity in a project reveals the non-predictable and non-linear nature of the project. Dynamic complexity can be used as an integrated measure of the internal contributing factors to uncertainty that are generated and evolve during the project life cycle and are not known at the beginning.

External Source of Disruption

The last dimension in the project environment of uncertainty is related to the external source of disruption. External sources of disruption are different from static or dynamic complexity in that they arise from the external environment. External sources of disruption such as natural disasters (e.g. flood and hurricane) and socio-political events (e.g., political instability and financial recession) are important factors affecting project uncertainty. Although the risks or opportunities due to the external sources of disruption may not happen in every project, it could significantly influence the project outcomes once they occur.

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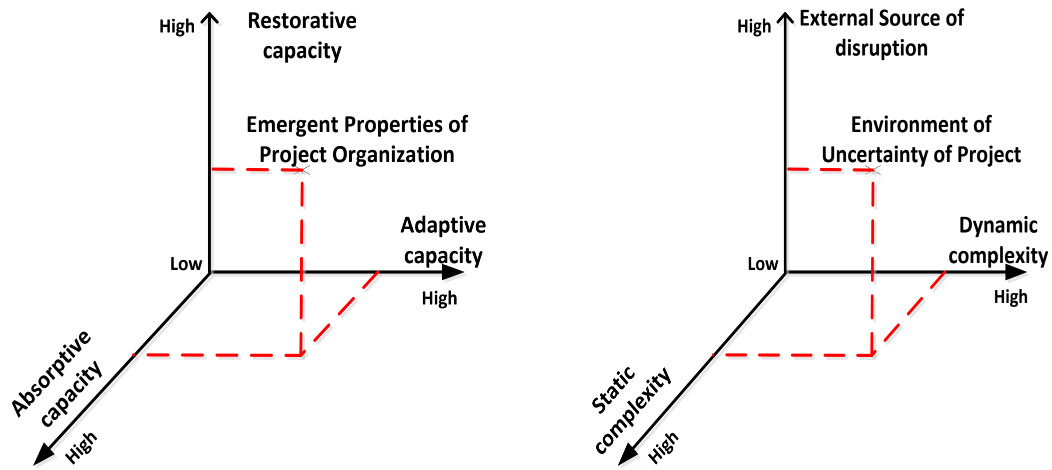
Impacts on Project Performance

Based on the analysis, the emergent properties (Figure 1(a)) and environment of uncertainty (Figure 1 (b)) of each specific project can be assessed as *integrative attributes*. Since the level of fitness between the environment of uncertainty and the ability of project organizations to cope with uncertainty determines the extent to which the performance outcomes are affected, there is a potential for the performance of a project to be investigated at the interface of emergent properties and uncertainty in terms of the likelihood of *variation*s in the performance outcomes (Figure 2). For example, the likelihood of cost overruns increases if a project organization with a low adaptive capacity operates in an environment with significant dynamic complexity. In contrast, a project organization can reduce the likelihood of performance variations in a highly uncertain environment by increasing its absorptive, adaptive, and restorative capacities. However, investigation of the impacts of emergent properties and environment of uncertainty on the performance variations of projects is beyond the scope of study presented in this paper.



(a) (b)

Figure 1 (a) Dimensions of Emergent properties (b) Dimensions of Environment of Uncertainty

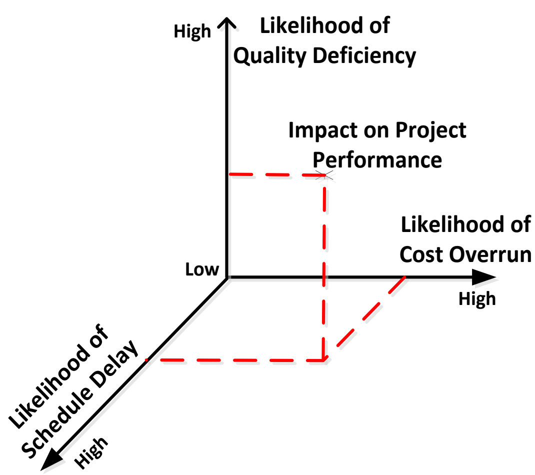


Figure 2 The Possible Impact of Fitness between Emergent Properties and Environment of Uncertainty on Project Performance

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METHODOLOGY

In order to test the proposed framework and its dimensions, we conducted a qualitative comparative analysis using case studies in the context of construction project organizations. A case-based research approach (Eisenhardt, 1989) was adopted in this study. Qualitative data was collected through interviews with senior construction project managers with years of experience. Our embedded unit of analysis (Yin, 2009) was cases of construction projects. Qualitative comparative analysis was conducted based on within-case analysis or cross-case pattern search. All of the interviewees had rich experience in managing different types of construction projects. Hence, they were able to provide comparative insight regarding different project organizations in terms of the emergent properties and environment of uncertainty. In the following section, the process related to collection and analysis of data is explained.

Crafting Protocols

The protocol for conducting the interviews included open-ended questions related to the dimensions of emergent properties and the environment of uncertainty in construction project organizations. The questions were divided into two sections. The questions in the first section were related to the environment of uncertainty in construction projects, and the ones in the second section were related to the emergent properties of construction project organizations. At the beginning of each section, a brief introduction was given to the interviewees to provide the background information and lead them to link the context with their experiences across different projects. The objective of the questions was to ask the interviewees to provide instances from their previous projects that reveal the dimensions of emergent properties and environment of uncertainty in construction projects. Two examples of questions included in the protocol are listed below:

- *While some of the factors contributing to uncertainty do not change over time, there are also factors contributing to project complexity and uncertainty which evolve and show up during the life cycle of the construction project (e.g. unexpected human agent actions, or delayed material delivery). Have you ever experienced the increase of project complexity and uncertainty caused by such factors? Can you give us some examples of construction projects in which complexity and uncertainty increased during the life cycle of the projects and what are the consequences?*
- *Most of the time, the project design, organizational structure, or execution process would have changed to some extent to adapt to the unexpected events happened during the life cycle of a construction project. Do you have the experience with such situations? Do you find there is a difference between different project organizations in their speed and ease in adapting to changes? Can you give us some examples of construction project organizations which have adapted to the changes of the project environment in a timely manner? What specific traits can you find in those project organizations?*

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The objective of the former question was to lead the interviewee to explain his/her experience from the previous projects and elaborate about dynamic complexity as one of the dimensions of uncertainty in project environment and get information about whether and how dynamic complexity affects the project performance. The later question was related to adaptive capacity as one of the emergent properties identified in project organizations. The objective of asking this question was to verify that different levels of capabilities in terms of adaption can be observed across project organizations and the capabilities affect project performance.

Data Collection

Seventeen senior project managers in the construction industry in the U.S. participated in the interviews. The interviewees had ten to twenty-five years of work experience as project managers. On average, each interviewee had participated in more than ten construction projects of different types (e.g. commercial, residential, and healthcare facility) as a project manager. Thus, our analysis was based on a database consisting more than one hundred and seventy construction projects. Among the seventeen interviews, three were conducted on the telephone, and the rest were conducted face-to-face. Each interview lasted between forty-five minutes to one hour. A snowball sampling (referral sampling) method was used to identify the interviewees. The snowball sampling method yields a study sample through referrals made among people who share or know of others who possess some characteristics that are of research interest (Biernacki and Waldorf, 1981). Using the snowball sampling methods, senior project managers with a wealth of experience can be reached in a short period of time. During the course of the research, a group of two researchers were conducting the interviews together. The two interviewers had independent roles. One interviewer took lead in asking questions, while the other interviewer recorded notes and made observations. This allowed the case to be captured by individuals with different perspectives.

Data Analysis and Results

In this study, NVivo was used for coding the interview transcribes to confirm the existence and significance of the dimensions of emergent properties and environment of uncertainty in projects in which the interviewees had been involved. To achieve this purpose, six nodes were created in NVivo: *absorptive capacity*, *adaptive capacity*, *restorative capacity*, *static complexity*, *dynamic complexity*, and *external source of disruption*. The keywords and phrases which signified these nodes in the responses were identified and coded. Similar patterns and frequent occurrence of these nodes in the data were used to verify the existence and importance of these dimensions, and justified the significance of the proposed framework. The findings from the data analysis are illustrated in the following section.

Static Complexity

Most of the interviewees confirmed that static complexity exist in construction projects. The most common keywords and phrases identified in the responses of the interviewees which

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signified the existence of static complexity are listed in Table 1. As a counter intuitive finding, senior project managers acknowledge that project size is not a significant factor for project complexity or uncertainty. As one of the interviewee said, "*A small project can be very complex, while a big project can be very simple*." Instead, project type (whether it is a new project or renovation project, or whether it is a single family house or healthcare facility) has been recognized as a major contributor to static complexity. For example, one of the project managers indicated that "*Renovation projects are the most difficult ones. As-built drawings usually do not provide enough information, and you will never know what you will see when you open the ceilings*." Other aspects pertaining to static complexity include project location, implementation of new technology, and existing jobsite conditions. Examples were provided by interviewees regarding to how these factors caused different levels of complexity and uncertainty in different construction projects and led to different project performance outcomes. For example, projects in different locations have different levels of uncertainty because "*Projects in urban areas have limited room to lay down equipment and place material*." One project managers mentioned that "*Sometimes streets even need to be shut down to set up the crane for projects in urban area, which is very likely to affect the project schedule.*"

Table 1 Keywords and Phrases for Node of Static Complexity

Node	Examples of keyword and Phrase
Static Complexity	Project type, project location, technology, existing conditions

Dynamic Complexity

Dynamic complexity determines the contributing factors to uncertainty which are generated during the project. Several keywords and phrases were identified from the interviewees' responses representing different levels of uncertainty due to dynamic complexity in construction projects (Table 2). Dynamic complexity is mainly due to the behaviors of different participants in the project organization networks. For example, many senior project managers had experiences related to dealing with "*changes of owners' requirements without giving enough time*", which create difficulties for them to keep the project cost and schedule under control. "*Additional requirements coming from the authorities having jurisdiction such as building officials and fire marshals*" is also a major factor affecting the dynamic complexity of a project. These changes in the requirements during the project have a great impact on performance outcomes since "*changes in one aspect will cause several corresponding changes. Moving the wall a couple of feet will lead to changes of location of ductwork, electrical equipment and mechanical systems.*" Errors and omissions is another significant factor affecting the dynamic complexity. Construction project work is conducted by humans. Humans, especially inexperienced and unskilled human agents in construction projects make mistakes. According to the cases provided by the interviewees, examples of human errors and omissions in construction projects include "*ordering inappropriate material*", "*installing inappropriate product*", "*unsafe act*" and "*violating working regulations*". One interviewee specifically emphasized the impact of

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risk attitude of workers on the level of uncertainty: "*There are more risk takers in some of the project organizations. For example, people in steel industry are referred to as cowboys as they are used to working in great height. So if there are more steel workers in one project, it is more likely for them to take short cut in work and create problems.*" Delays in delivering material and equipment to the jobsite is also recognized as an operational factor contributing to complexity and uncertainty. Unavailability of the required material and equipment will not only affect one activity or process, but also all the successor activities and processes.

Table 2 Keywords and Phrases for Node of Dynamic Complexity

Node	Examples of Keyword and Phrases
Dynamic Complexity	Change of owners' requirement, additional requirement by authorities, error and omission, unavailability of material and equipment

External Source of Disruption

The external source of disruption is related to changes in the environmental, social, economic and political context. Different projects have different levels of uncertainty related to the external source of disruption. Examples related to the external sources of disruption mentioned by the interviewees include natural disasters, economic fluctuations, and strike (Table 3). The interviewees provided examples of delays and damages to their projects due to natural disasters such as hurricane and flood. For example, one interviewee mentioned that: "*Whenever hurricane comes, you need to shut down at least five to ten days.*" Definitely, this kind of shut down would affect project performance. Another example pertaining to the external source of disruption is economic and market fluctuations. Economic and market fluctuations affect the project outcomes through its impact on the availability of labor and material. For example, one interviewee gave us an example related to the impact of economic and market fluctuation on construction projects in South Florida: "*For the past couple of years, much of the construction labor force left for other states or industries because of the slowdown in construction industry due to the economy depression. Now that the economy is turning around and the construction industry starts to grow in South Florida, the availability of the labor force is limited.*" Fluctuations in the economy also affect the availability of material because "*When material price rises, it is not easy to order and store material ahead of time.*" Because of the significant influence that the external sources of disruption could bring, it is necessary for project organizations to be capable to cope with the uncertainty.

Table 3 Keywords and Phrases for Node of External Source of Disruption

Node	Examples of Keyword and Phrases
External Source of Disruption	Natural disaster, economic and market fluctuation, strike

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The project environment of uncertainty could affect the project performance. According to one of the interviewees, "*The success of the project is based on how efficient we address these issues as they come up, or even before they come up.*" The abilities in addressing these issues by coping with uncertainty are identified as emergent properties in our framework. Similar to the dimensions of environment of uncertainty, we investigated the existence and significance of the three emergent properties in project organizations using the data obtained from interviews.

Absorptive Capacity

Most interviewees confirmed that they experience different levels of absorptive capacity in different project organizations. The existence of absorptive capacity was captured using the keywords and phrases listed in Table 4. For example, planning during the pre-construction phase is critical for enhancing the absorptive capacity of the project organizations. Project organizations with high level of absorptive capacity analyze information and adopt strategies to address the problems in early stages of a project. Examples of planning actions leading to a greater absorptive capacity in project organizations include: "*avoiding scheduling certain activities during the hurricane season such as pouring concrete*", "*eliminating possible conflicts between different trades by coordination of Mechanical, Electrical, and Plumbing (MEP) Systems from the design phase*", and "*placing early purchase order for material and equipment and locking in the price with suppliers*".

The absorptive capacity of a project organization cannot be attributed to a single entity, constituent, or process. As indicated by one interviewee: "*The key is to ask participants to sit together, get familiar, understand the conditions, and address possible problems ahead of time together*." Coordination meetings involving different participants (e.g., owner, architecture, engineer, general contractor, and subcontractor) is an important approach to obtain absorptive capacity in project organizations. Enhancing the information flow in project organizations could also enhance the absorptive capacity of project organizations. Several interviewees mentioned their observations pertaining to the impact of using information technologies such as building information modeling (BIM) on the absorptive capacity in project organizations. Project organizations which implemented BIM in their projects improved the information exchange and coordination process between different participants. Possible conflicts in design and construction were diagnosed and addressed in the early stages.

Table 4 Keywords and Phrases for Node of Absorptive Capacity

Node	Examples of Keyword and Phrases
Absorptive Capacity	Pre-construction, plan ahead of time, good relationship between participants, implementation of BIM

Adaptive Capacity

Adaptive capacity is the emergent property that was most widely recognized among the interviewees. According to one of the interviewees, *"Our industry is built on estimation. But*

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estimation is not guaranteed. Weather, labor, and resource are all factors that cannot be fully controlled. The ability to deal with circumstances which are not in the plan is important. If we cannot get material from somebody, we go to somebody else. If subcontractor doesn't perform well, we may need to find a substitute. If we find contaminated soil in foundation work, we bring it to the attention of owner and architect and make adjustment together. We are constantly adapting to the things we cannot control."

According to our analysis, different levels of adaptive capacity in project organizations are mostly affected by the speed of decision making, level of bureaucracy, ability to consider different alternatives, and communication and coordination skills (Table 5). There was one example provided by the interviewee in which a project organization showed high level of adaptive capacity: "*Due to late delivery of material, we just change the activity sequence to do as many of other activities first and leave room for whatever is coming late. In this process, more than one activity and participant were involved.*" Adaptation to new situations can be better achieved by a mutual understanding and decision making. In contrast, the interviewees highlighted examples of low levels of adaptive capacity in some project organizations: "*Bureaucracy in some of the project organizations is a big problem that hinders the flow of information and decreases the adaptive capacity. To make a change in design to cope with emerging issues on the jobsite, I need to deliver different documents to different offices and get them reviewed and approved. By the time I finally got it back, one week had already past.*"

Table 5 Keywords and Phrases for Node of Adaptive Capacity

Node	Examples of Keyword and Phrases
Adaptive Capacity	On-spot decision, less bureaucracy, ability to propose alternatives, communication and coordination

Restorative Capacity

Restorative capacity is related to the ability of a project organization to recover from the uncertainty-induced disruptions in the processes. Not every project organization has quick recovery after the uncertainty-induced disruptions. Examples of factors that signify different levels of restorative capacity in project organizations are shown in Table 6. One interviewee highlighted his experience during hurricane Katrina: "*After the hurricane flooded part of the jobsite, I just called workers immediately and ask them to come to work during night time and fix the damaged exterior wall to stop more water coming in without waiting for change orders. With this quick reaction, the hurricane just delayed the schedule by a few days, which can be considered as a minimum impact to the project performance.*" In some other cases mentioned by the interviewees, if such quick reaction is not taken, disruptions like hurricane can cause severe damages to the project. Restorative capacity in a project organization arises from the interdependencies between different participants. According to one interviewee, "*making everyone responsible*" is critical for restorative capacity of the project organizations. Project organizations which have better collaborative relationships between the participants usually have

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greater levels of restorative capacity, and thus, have less likelihood to experience performance deviations.

Table 6 Keywords and Phrases for Node of Restorative Capacity

Node	Examples of Keyword and Phrases
Restorative Capacity	Quick reaction, make everyone responsible, collaboration

One important observation made pertaining to emergent properties in project organizations is that, although there are three independent dimensions of emergent properties representing different aspects of project organization's ability in coping with uncertainty, the three dimensions are closely interrelated. Several features of the project organizations, such as communication and coordination, information flow, and collaboration affect all the three dimensions of emergent properties. Besides, these three emergent properties sometimes can affect each other. For example, as one of the interviewees highlighted, "*The absorptive capacity will dictate the level of adaptive and restorative capacity.*"

CONCLUSION

In this paper, an integrated framework was proposed to investigate the emergent properties affecting the ability of project organizations to cope with uncertainty. Based on the proposed framework, the likelihood of project performance deviation could be investigated at the interface of project organization's ability to cope with uncertainty and project's environment of uncertainty. The proposed framework was tested using the data obtained from interviews with senior construction project managers in construction industry. The analysis of the data verified the existence and significance of three dimensions of emergent properties which represent the ability of project organizations to cope with uncertainty: absorptive capacity, adaptive capacity and restorative capacity. The analysis also verified the three dimensions of environment of uncertainty in projects: static complexity, dynamic complexity and external source of disruption. The proposed framework provides a novel perspective to investigating the performance of project organizations at the interface of emergent properties and uncertainty. A better understanding of emergent properties in project organizations could enhance our understanding of the situations leading to performance inefficiencies in project organizations. The emergent properties could also be used as leading indicators for proactively enhancing the ability of project organizations to cope with uncertainty. For example, reduction of a beneficial emergent property (e.g., adaptive capacity) might not immediately lead to a decrease in performance measures (e.g., cost overrun); however, if proactive actions are not taken, it ultimately could affect project performance. Thus, the investigation and control of emergent properties could facilitate the proactive management of performance in construction projects. Decision-makers in project organizations could use the created methodology to design project organizations during the planning phase and to proactively manage performance measures during the design and construction phases. The next step of the research is to identify quantitative measures for the emergent properties and environment of uncertainty in complex projects and quantitatively

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investigate the impacts emergent properties and the environment of uncertainty on the performance outcomes of the project.

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