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IDENTIFICATION AND QUANTIFICATION OF PROJECT COMPLEXITY FROM PERSPECTIVE OF PRIMARY STAKEHOLDERS IN US CONSTRUCTION PROJECTS

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Abstract. Construction experts believe that complexity could adversely affect construction projects' performance. Several studies have been focused on identifying leading complexity indicators; however, the complexity indicators from the perspective of primary stakeholders (owners, contractors, and consultants) have been rarely studied. Therefore, the aim of this study is to utilize the systematic Delphi method to identify, rank and weight the complexity indicators based on the primary stakeholders' perspectives associated with US construction projects. Additionally, the shared entity-based complexity indicators (ECIs), as well as the weighting of entity-based complexity categories were determined and analyzed. Therefore, 101 potential ECIs were identified through a comprehensive literature review. Then, thirteen senior subject matter experts (SMEs), and three academic advisors were selected and invited to participate in a workshop to determine significant ECIs and then rank and weight them. The results reveal that the ECIs associated with complexity categories "scope definition" and "project resources" received the highest aggregated complexity weights in the aspect of the primary stakeholders. Although this study has been conducted based on US construction projects, the results would provide helpful guidance for international construction projects. Moreover, this study would assist the primary stakeholders in allocating resources properly in order to manage project complexity worldwide.

Keywords: construction project, project complexity, primary stakeholders, complexity indicators, indicator weighting, indicator ranking.

Introduction

Complexity is a term often used in the literature and among practitioners to describe one of the causes of cost overruns, schedule delays, and poor project performance (Remington & Pollack, 2007; Thomas & Mengel, 2008; Ahn, Shokri, Lee, & Haas, 2017; Luo, He, Xie, Yang, & Wu, 2017; Safapour, Kermanshachi, Habibi, & Shane, 2018). A thorough understanding of project complexity is essential for effective management; therefore, many researchers have focused on this subject (Brockmann & Girmscheid, 2007; Maylor, Vidgen, & Carver, 2008; Remington, Zolin, & Turner, 2009; Vidal, Marle, & Bocquet, 2011a; Bosch-Rekveldt, 2011; Gransberg, Shane, Strong, & Puerto, 2013; He, Luo, Wang, Li, & Zhao, 2012; Dao, Kermanshachi, Shane, & Anderson, 2017; Ahn et al., 2017; Kian Manesh Rad, Sun, & Bosche, 2017). Accordingly, different studies have been conducted to identify the complexity indicators and categorized them from various aspects and views (Baccarini, 1996; Vidal et al., 2011a; Bosch-Rekveldt, 2011; Lessard, Sakhrani, & Miller, 2014; Liu, 2015; He, Luo, Hu, & Chan, 2015; Dao et al., 2017) in order to recognize project complexity early in construction projects to manage them effectively (Vidal & Marle, 2008; Kian Manesh Rad et al., 2017). Sinha, Kumar, and Thomson (2011) explained that the factors and indicators of project complexity greatly depend upon social, environment, and context of the project. The mentioned authors believed that the determination of the project context, including work context, social and environmental context, geographical context, etc., is a prerequisite for studying of complexity. In terms of geographical context, some studies have been conducted to determine complexity indicators in a particular region such as China and Malaysia (He et al., 2015; Abdou, Yong, & Othman, 2016). While day-by-day, the considerable cost has been invested in the construction industry in the US country, there is a lack of sufficient study to determine complexity indicators for US construction projects.

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There is a need to measure complexity factors and indicators precisely in order to effectively control and manage project complexity. Several researchers have tried to determine the significance (weight) of each complexity indicator, and specify the scoring scales of these indicators (Vidal, Marle, & Bocquet, 2011b; Xia & Chan, 2012; He et al., 2015). However, not all complexity characteristics have the same negative effect and impact on project success (Lu, Luo, Wang, Le, & Shi, 2015), which makes it important to understand and quantify weight of each complexity parameter and its impact on the overall project complexity level.

Furthermore, as the primary stakeholders require focusing on complexity factors corresponding to their work and responsibilities, determining the three primary stakeholders' perceptions of project complexity as well as the corresponding weights of the key factors are also considered as vital information for management of project complexity. As stated earlier, although multiple researchers have attempted to identify complexity indicators and attributes, no study identified, ranked and weighted the complexity indicators based on the perspectives and input of the three primary stakeholders. Therefore, the overall goal of this paper is to fill this gap in the knowledge. Thus, this study seeks to answer the following questions:

Q1. What are the complexity indicators corresponding to the perspective of three primary stakeholders?

Q2. What are the ranking and weighting of the identified entity-based complexity indicators?

Q3. What are the shared complexity indicators among three primary stakeholders?

Q4. What are the comparison results of the entity-based weighting of complexity categories?

The following objectives were formulated to answer the research questions: (1) identify the complexity indicators from perspective of each primary stakeholder; (2) rank the entity-based complexity indicators; (3) weight the entity-based complexity indicators; (4) identify the shared complexity indicators among three primary stakeholders; and (5) compare the entity-based weighting of complexity categories among three primary stakeholders. Primary stakeholders could utilize the outcomes of this study to formulate a project complexity assessment and management model in order to select the most appropriate complexity strategies for mitigating the complexity of construction projects.

1. Literature review

Many researchers have described complexity as a critical topic in the area of project management research (Gidado, 1996; Hass, 2008; Owens, Ahn, Shane, Strong, & Gransburg, 2011; Bosch-Rekveldt, 2011; Lehtiranta, 2011; Puddicombe, 2012; Ahern, Leavy, & Byrne, 2013; Lu et al., 2015; Abdou et al., 2016; Kiridena & Sense, 2016; Ji, AbouRizk, Zaiane, & Li, 2018). The meaning of the word "complexity" was ambiguous and lacked a standard definition for many years. Thus, the researchers had challenged to find a unique and standard definition of complexity (Sinha, Thomson, & Kumar, 2001). Simon (1969) and Kauffman (1993) stated that project complexity involves various actions and states of the world parameters as they interact. Remington and Pollack (2007) defined project complexity as "*interrelationships and feedback between increasing numbers of areas of uncertainty and ambiguity.*" Similarly, Vidal et al. (2011a) defined project complexity as "*the property of a project which makes it difficult to understand, foresee and keep under control its overall behavior, even when given reasonably complete information about the project system.*" Recently, Dao et al. (2017) conducted a comprehensive complexity research, which reviewed and examined all of the previous studies corresponding to complexity definitions. The mentioned authors defined project complexity as "*the degree of differentiation of project elements, interrelatedness between project elements, and consequential impact on project decisions*." Accordingly, the authors of the present study followed the latest study conducted by Dao et al. (2017) and their definition of the project complexity.

Many scholars and researchers have recognized and documented the importance of complexity measurements in project analysis, especially in large-scale construction projects, because it can serve as a reference for policymakers (Wiendahl & Scholtissek, 1994; He et al., 2015; Qureshi & Kang, 2015; A. T. Nguyen, L. D. Nguyen, Le-Hoai, & Dang, 2015; Dao, Kermanshachi, Shane, & Anderson, 2016; Kermanshachi, Dao, Shane, & Anderson, 2016a; Kermanshachi, Dao, Rouhanizadeh, Shane, & Anderson, 2018; Priyadharsini & Rathinakumar, 2018). In addition, complexity measurement is necessary for managing large-scale projects, as it is difficult to control what cannot be measured (DeMacro, 1982). Accordingly, the complexity measurement assists in determining which elements make a project complex (Luo et al., 2017). Sinha and Singh (2006) introduced a framework to measure project complexity in the form of an index. Wood and Ashton (2010) developed a model, using a combination of methods to measure complexity during the early stages of a project. Similarly, Vidal et al. (2011a, 2011b) identified 18 complexity indicators in order to develop a model to measure project complexity level using analytic hierarchy process (AHP). In another study, Xia and Chan (2012) utilized Delphi method and importance index method in order to measure six identified complexity indicators. He et al. (2015) identified 28 complexity indicators and classified into six categories as technological, goal, information, and organizational, cultural, and environmental complexities. Then, these authors utilized fuzzy analytic network process (FANP) and Delphi method to calculate and record corresponding weight of indicators. Shafiei-Monfared and Jenab (2012) used a complexity design structure matrix (CDSM) to quantify the relative complexity of design projects. Additionally, a model using ProjectSim software was developed by Lu et al. (2015) to measure the level of complexity in projects.

Many studies have been performed to identify and categorize the key factors of project complexity (Lessard et al., 2014; Liu, 2015; He et al., 2015; Kermanshachi, Dao, Shane, & Anderson, 2016b). Since Baccarini (1996), who is one of the leading researchers, categorized project complexity into organization and technology, and so most of the later studies were inspired by the outcome of his research. Similarly, Maylor (2003) categorized the elements of project complexity into three groups: organization, resource, and technique. Remington and Pollack (2007) classified complexity into four categories: structural, technical, directional, and temporal complexity. Bosch-Rekveldt (2011) likewise presented project complexity as technological, organizational, and environmental (TOE). Liu (2015) introduced a technology-organization hierarchy of project complexity. The mentioned authors classified the complexity factors into two main categories of task and organization complexity factors. Senescu, Aranda-Mena, and Haymaker (2012) presented three categories of product complexity, organizational complexity, and process complexity. Gao, Chen, W. Wang, and Y. Wang (2018) adopted TOE project complexity categories and differentiated quantitatively among these categories.

The Delphi technique is known as one of the best methods for reaching a consensus by utilizing a set of pre-defined questions to collect data from a group of SMEs (Dalkey & Helmer, 1963; Lindeman, 1981; Martino, 1983; Young & Jamieson, 2001; Chan, Yung, Lam, Tam, & Cheung, 2001; Okoli & Pawloski, 2004; Xia & Chan, 2012; Perera, Rameezdeen, Chileshe, & Hosseini, 2014). The Delphi method refers to an organized iterative procedure for consensus and agreement that is commonly reached after some rounds of feedbacks of subject matter of experts' assessment and judgment on a particular subject. Utilization of Delphi method assists in obtaining reliable results (user can be confident with the measure), as this method is a systematic and interactive research technique for recording the judgment of a panel of independent subject matter of experts on a particular topic (Hallowell & Gambatese, 2010).

The Delphi has been a popular method in the area of construction engineering and management (CEM), as CEM is inherently a practice driven field. Because most of the research issues and concerns in CEM need to be addressed by practitioners, who have work experiences on construction management activities (Fellows & Liu, 2009). Accordingly, Chan et al. (2001) claimed that the Delphi method is very beneficial to prepare a more reliable and effective alternative for addressing CEM issues. Thus, many researchers in the CEM area have implemented Delphi method through the last decades (Manoliadis, Tsolas, & Nakou, 2006; Yeung, A. P. C. Chan, & D. W. M. Chan, 2009; Xia & Chan, 2012; Yik, Lai, Lee, Chan, & Chau, 2012). For the reasons mentioned above, the Delphi method was found to be the best method for identifying, weighting and ranking of the entity-based complexity indicators.

There is a current gap of knowledge pertaining to identifying, ranking and weighting of ECIs in existing literature. Therefore, a thorough investigation and analysis of complexity indicators corresponding to each primary stakeholder are required. As a result, the focus of this study is to identify, rank, and weight the complexity indicators in aspect of primary stakeholders with the utilization of the Delphi method. The shared ECIs among three primary stakeholders were then investigated. Next, the results of the weighting associated with ECIs' categories were compared among the stated stakeholders.

2. Research methods

2.1. Research framework

To achieve the objectives of this study, a five-step structured methodology, as shown in Figure 1, was developed. This study was initiated with a thorough review of the literature to identify the comprehensive list of potential ECIs. Accordingly, 101 potential ECIs, belonging to 11 categories, were identified. In the third step, these identified indicators decreased to 38 potential ECIs by thirteen selected SMEs and three academic advisors. Then, through three rounds of the structured and systematic Delphi method, the SMEs with the help of three research advisors, identified and ranked the entity-based complexity indicators. Thus, the stated three lists of ECIs were finalized. Next, the research team utilized the ranking result of ECIs in order to calculate the weight of them. The results were used to determine the shared ECIs among three stakeholders and determine the entity-based weighting of complexity categories. Finally, the results were implemented, compared, and analyzed for three case study projects collected from industrial projects.

2.2. Delphi method

Using series of "rounds" for collecting data and information until reaching consensus by selected expert panelists is called Delphi method (Green, Jones, Hughes, & Williams, 1999; Hasson, Keeney, & McKenna, 2000; Powell, 2003). Through conducting the Delphi method, a list of questions is commonly presented to selected panelists in order to find out their opinion and feedback on a specific problem (McKenna, 1994; Chan et al., 2001). Generally, the Delphi method has been applied for forecasting, planning, and problem identification and periodization. This method is also employed to develop a structured framework (Okoli & Pawlowski, 2004).

Selection of knowledgeable and qualified experts is considered as one of the important steps of implementing Delphi method (Hasson et al., 2000; Cabaniss, 2001; Manoliadis, Pantouvakis, & Christodoulou, 2009; Ameyaw, Hu, Shan, Chan, & Le, 2016). Hallowell and Gambatese (2010) explained that a minimum eight number of panelist is sufficient for Delphi technique. Accordingly, the research team of the present study selected and invited thirteen SMEs and three academic advisors to attend one full-day complexity identification and assessment workshop, which was divided into the two – morning and after-

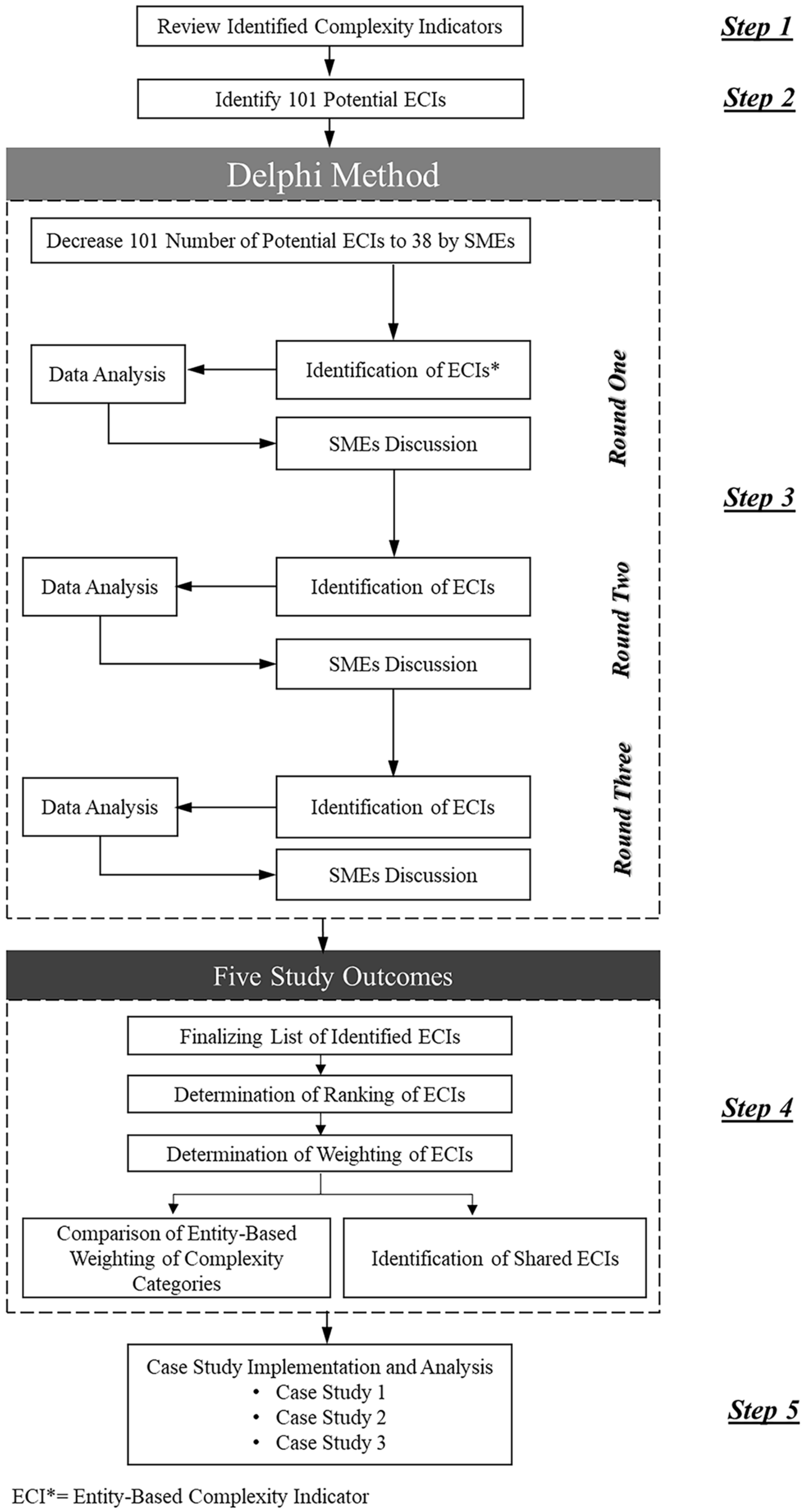

Figure 1. Research framework

noon – sessions, and also lasted for more than seven hours. All of the selected SMEs had considerable work experience in the three primary stakeholders corresponding to construction projects. Additionally, the research team had more three major criteria for selecting SMEs. First, each of the SMEs was supposed to have at least 15 years of related work experience in US construction projects. Second, they were required to have a work experience on at least two large-scale complex projects located in US. Third, they should have had work experience, knowledge, and understanding of all primary stakeholders. Then, three research advisory members who were called academic advisor with sufficient knowledge about complexity and had experience, knowledge, and understanding of US construction projects, were invited to help the academic research team. Table 1 shows demographic information of the academic advisors and SMEs.

To achieve accurate and quality results, the initial list of 101 ECIs, belonging to eleven categories, were sent to the SMEs two weeks prior to the workshop. This information was also presented briefly at the beginning of the workshop to ensure that the SMEs had a clear understanding of the complexity and its indicators. The SMEs reduce the list of potential ECIs to 38 potential ones after a one-hour discussion. The SMEs believed that these 38 potential ECIs are very important indicators in terms of making a project complex.

Table 2 depicts the 38 stated complexity indicators belonging to 11 categories. Each category with some indicators was measured. For instance, ECI-6 "number of times on a project that a change order will go above the PM for approval" aims to measure the "governance" complexity category. Then, the SMEs were asked to rank each of the potential 38 ECIs according to their level of impact on the complexity of a project.

The number of rounds is a critical factor in order to reach consensus among panelists through the process of implementing Delphi method (Hallowell & Gambatese, 2010). Since there is no particular guideline to define the optimal number of rounds regarding Delphi method in the existing literature, the researchers commonly continue the Delphi rounds in order to attain and record the favorable level of consensus (Ameyaw et al., 2016). Accordingly, Ameyaw et al. (2016) conducted a comprehensive study and found out the researchers reached the desired consensus after two and three rounds in approximately half of the conducted studies in the area of CEM. In this regard, the researchers of the current study reached the desired consensus when the results of the second round and third round were the same. The details of the Delphi method procedure are presented in Figure 2.

Some recognized issues and concerns associated with the reliability of the Delphi technique have been mentioned in the existing literature (Keeney, Hasson, & McKenna, 2001; Skulmoski, Hartman, & Krahn, 2007; Keeney, Hasson, & McKenna, 2011). Hasson et al. (2000) claimed that if different panels reach the same consensus with similar given information, the results of the Delphi method would be reliable. Similarly, Gupta and Clarke (1996) and Keeney et al. (2001) mentioned that poor choice of experts, limited feedback, and weak bias control are the other reasons related to the reliability of the Delphi method. On the contrary, Chan et al. (2001) believed that the Delphi technique is more beneficial compared to other methods such as interviews, to provide a more reliable and efficient for solving the issue with high uncertainty.

Table 1. Expert participants' demographic information in the panel

Delphi study groups	Number	Round(s)	Current role in the company	Years of experience in construction Industry
Subject matter experts (SMEs)	1	1, 2, 3	Project manager	35
	2	1, 2, 3	Business manager	21
	3	1, 2, 3	Project performance Analyst	15
	4	1, 2, 3	Executive manager	36
	5	1, 2, 3	Decision and value consultant	33
	6	1, 2, 3	Senior finance manager	32
	7	1, 2, 3	Operation manager	22
	8	1, 2, 3	Project manager	25
	9	1, 2, 3	Project manager	25
	10	1, 2, 3	Construction manager	23
	11	1, 2, 3	Construction coordinator	16
	12	1, 2, 3	Project executive	22
	13	1, 2, 3	Portfolio manager	27
Academic advisors	14	1, 2, 3	Professor	35
	15	1, 2, 3	Researcher	13
	16	1, 2, 3	Researcher	10

Table 2. Complexity categories and indicators

Category	Entity-Based Complexity Indicator (ECI)
Stakeholder Management	ECI-1. Influence of this project on the organization's overall success.
	ECI-2. Impact of required approvals from external stakeholders on the original project execution plan.
	ECI-3. Impact of required inspection by external (regulatory) agencies on original project execution plan.
Governance	ECI-4. Total number of joint-venture partners in this project.
	ECI-5. Number of executive oversight entities above the PMT who will have decision-making authority over the project execution plan.
	ECI-6. Number of times on this project that a change order will go above the Project Manager for approval.
Fiscal planning	ECI-7. Number of funding phases (gates) from concept to project completion. ECI-8. Specific delays or difficulties in securing project funding.
Quality	ECI-9. Quality of bulk materials during project execution.
Legal	ECI-10. Number of total permits to be required. ECI-11. Level of Difficulty in obtaining permits. ECI-12. Difficulty in obtaining design approvals.
	ECI-13. Impact of external agencies on the project execution plan.
Interfaces	ECI-14. Peak number of FTE participants on the PMT during detailed engineering/design phase of the project. ECI-15. Peak number of participants (FTE) on the PMT during the procurement phase of the project. ECI-16. Average number of participants (FTE) on the PMT during the detailed engineering/design phase of the project. ECI-17. Average number of participants (FTE) on the PMT during the procurement phase of the project.
Execution target	ECI-18. Compare target project cost against industry/internal benchmarks.
	ECI-19. Compare target project schedule against industry/internal benchmarks.
Design & technology	ECI-20. Difficulty in system design and integration on this project compared to a typical project for your company.
	ECI-21. Company's degree of familiarity with technologies that will be involved in detailed engineering/ design project phase. ECI-22. Company's degree of familiarity with technologies that were involved in construction phase. ECI-23. Company's degree of familiarity with technologies that were involved in operating facility project phase.
Location	ECI-24. Number of execution locations used on this project during detailed engineering/design phase.
	ECI-25. Number of execution locations which will be used on the project during fabrication (bulk materials and equipment) phase. ECI-26. Impact of the project location on the project execution plan.
	ECI-27. Level of infrastructure existing at the site to support the project. ECI-28. Project location is remote from highly-populated areas.
Scope definition	ECI-29. Identify the percentage of engineering/design completed at the start of construction. ECI-30. Clarity of the change management process to key project team members. ECI-31. Impact of the magnitude of change orders on project execution. ECI-32. Impact of the timing of change orders on project execution. ECI-33. RFIs drive project design changes.
Project resources	ECI-34. Percentage of project/construction management staff who work on the project compared to planned project/construction management staff. ECI-35. Quality issues of skilled field craft labor during project construction.
	ECI-36. Frequency of workarounds because materials were not available when needed to support construction.
	ECI-37. Percentage of craft labor turnover. ECI-38. Percentage of craft labor sourced locally.

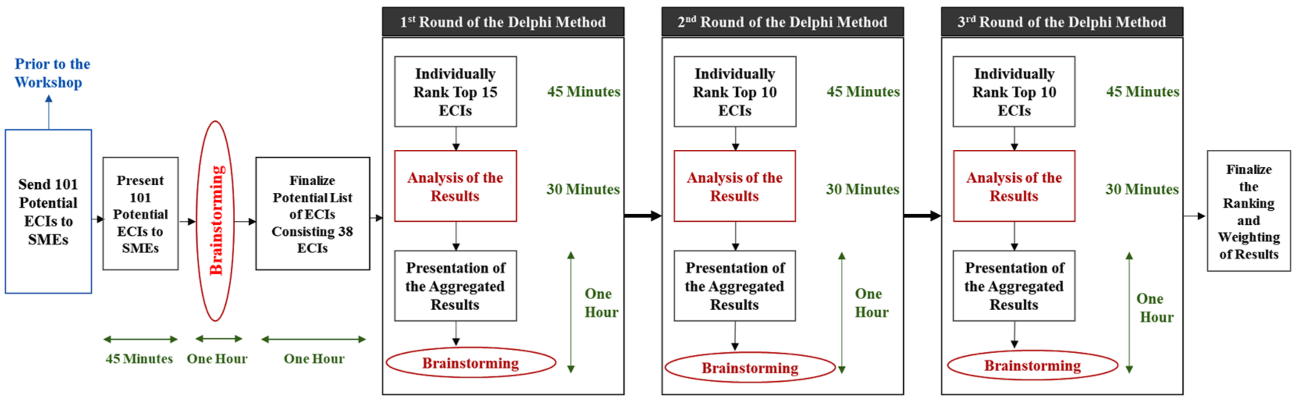

Figure 2. Procedure of the Delphi method

As stated earlier, CEM is inherently a practice-driven field. So to address the research questions associated with CEM, the experience of SMEs, and expert individuals and organizations who are involved in construction engineering and Management should be considered (Fellows & Liu, 2009). The key to resolve this issue should completely rely on the collective knowledge, experience, and judgment of selected experts and qualified professionals in the field of CEM. Thus, many studies have implemented Delphi technique in CEM research from the 1990s (Hallowell & Gambatese, 2010) particularly for identifying, evaluating, and forecasting purpose in this area (Ameyaw et al., 2016).

As the main objective of the current study is to identify and quantify the complexity indicators associated with each of primary stakeholders for U.S. construction projects; thus, the authors adopted the Delphi technique in order to use knowledge, experience, opinion, and judgment of SMEs. Accordingly, the authors carefully selected panels based on the experience, role, and region. Moreover, when the results of round 2 and round 3 were exactly the same as each other, the research team avoided conducting any further round. Moreover, as accurate judgments were guaranteed by the absence of pressures on each of the panelists through all rounds of Delphi technique, who are involved US construction projects and academics. All of the selected panelists were interested in involving in all procedures of the Delphi method adopted in this study.

Finally, the research team then performed quantitative data analysis on the collected data while the SMEs took a short break and discussed their points of view in small groups. Multiple statistical analyses were performed to find the ECIs' aggregated ranking.

2.3. Rank sum weight method

In rank sum weight (RSW) method, the weights associated with variables are calculated based on dividing the individual ranks by the sum of the ranks (Stillwell, Seaver, & Edwards, 1981). Generally, to calculate the variables' aggregated ranking, there is required to calculate the variables' aggregated score. For this purpose, each variable's ranking was transformed to the variable's score, based on the following Eqn (1):

$$S_i = N - R_i + 1, \quad (1)$$

where S_i is a variable's score based on the ranking of each variable, N is the total number of variables, and R_i is the ranking assigned to each of the variables. The total score for each variable is then calculated according to Eqn (2), where S_i represents a calculated score based on the variables' ranking.

$$S_T = \sum_{i=1}^{N} S_i. \quad (2)$$

The weight of variables is calculated by the ratio of the score of each variable over the sum of all the variables' scores as follows:

$$wt_i = \frac{\mathrm{Si}}{\mathrm{S_T}}, \quad (3)$$

where wt_i represents "weight of the ith variable".

3. Delphi method implementation process

3.1. Delphi questionnaire: Round 1

The SMEs were asked to complete the distributed handouts in the workshop to rank the ECIs associated with each entity, as shown in Figure 2. In these handouts, the 38 identified complexity indicators were listed randomly. The experts were given 45 minutes to select and rank the top 15 complexity indicators individually according to the perspective of each entity in descending order, based on their level of impact on project complexity. All handouts were collected and then the scores were calculated based on the ranking that was assigned to the indicators. Accordingly, the total ECIs' scores were sorted in descending order. Next, the ranking associated with 15 ECIs was calculated using the RSW method.

The results of the first round showed that all the ECIs in the sample were selected at least once by SMEs. Before entering the second round of the Delphi method, the research team informed the SMEs with the results of the first round and then organized another one-hour brainstorming session.

3.2. Delphi questionnaire: Round 2

In the second round, the aim was to eliminate the low-scored ECIs as well as the ones not selected by the SMEs through brainstorming. However, the sample size was reduced to "10", as shown in Figure 2. Accordingly, the SMEs were asked to select top 10 ECIs based on their experience and from perspective of three primary stakeholders. RSW method was utilized in order to calculate the weight associated with each of the identified ECIs. In this method, when there is a number of alternatives and decision criteria, the importance of each alternative will be calculated by summation of multiplication of the weight of the criteria by its performance value. Once the aggregated ranking results in the second round were calculated, the results of the second round were presented to the SMEs. Before starting the third round of the Delphi method, the research team informed the SMEs with the results of the second round and then organized another one-hour brainstorming session. The SMEs were again given another one hour to finalize their second round ranking lists, after which the research team once again collected the handouts and performed the analysis based on RSW method.

3.3. Delphi questionnaire: Round 3

As shown in Figure 2, the SMEs were asked to again rank the top 10 ECIs based on their experience and perspective of each stakeholder in order to check if their input has been changed based on the second brainstorming session and then results were compared with those of defined ECIs in the second round. Since the comparison showed that individual rankings did not change, the fourth round was not conducted and the process was stopped. Next, the research team informed the SMEs with the results of the third round and then organized another one-hour brainstorming session. The main reason behind this brainstorming session was to give them an opportunity to provide the input and share their different points of view as owners, consultants, and contractors. After another one-hour discussion, the SMEs insisted that their individual ranking results were final and will not be changed, and the final ranking list was used to calculate the ECIs' weight.

Table 3. Identified complexity indicators corresponding to contractor's perspective, ranking, and weighting of them

ECI #	Complexity Indicator	Round 1		Round 2 & 3*		Weight (%)
		Score (S_i)	Rank (R_i)	Score (S_i)	Rank (R_i)	
32	Impact of timing of the change orders	15	7	17	1	9.88
31	Impact of magnitude of the change orders	12	10	17	1	9.88
36	Frequency of workarounds	28	1	14	2	8.13
4	# of joint-venture entities	8	13	14	2	8.13
26	Impact of project location on the project execution plan	14	8	13	3	7.55
30	Clarity of change management process project team members	12	10	11	4	6.39
35	Field craft labor quality issues during construction	26	2	10	5	5.81
27	Level of infrastructure existed at the site	0	0	10	5	5.81
2	Impact of required approvals from external stakeholders	17	6	10	5	5.81
14	Peak # of FTE on the PMT during design Phase	28	1	10	5	5.81
20	Difficulty in system design and integration	26	2	9	6	5.23
28	Project location remoteness	2	18	8	7	4.65
10	# of total permits to be required	0	0	7	8	4.06
19	Schedule targets compared to industry/internal benchmarks	13	9	6	9	3.48
25	# of execution locations during fabrication	0	0	4	10	2.32
9	Quality of bulk materials during project execution	0	0	3	11	1.74
38	Percentage of craft labor sourced locally	1	19	2	12	1.16
34	Quality issues of skilled field craft labor during project construction	6	15	2	12	1.16
22	Company's familiarity with technologies in construction phase	0	0	2	12	1.16
5	# of executive oversight entities above the PMT	8	13	1	13	0.58
37	Percentage of craft labor turnover	15	7	1	13	0.58
29	Percentage of design completed at the start of construction	15	7	1	13	0.58

Note: *As the results of rounds 2 and 3 were the same, their corresponding score and ranking values are demonstrated in one column.

Tables 3, 4, and 5 show the results of the first and third round ECIs' score and ranking. It should be noted that as the ranking results did not change, so the results of the second and third rounds were presented in the same column.

After the results were finalized, the three ranking lists of the ECIs were presented to the SMEs. The SMEs then compared these lists with the first round aggregated results and expressed their opinions about the reasons for their ranking selections.

4. Study outcomes

4.1. Identification of ranking and weighting of ECIs

The three lists of entity-based complexity indicators in aspect of three primary stakeholders were finalized. Although the ranking list corresponding to each entity shows the prioritized list of ECIs, it does not clarify the difference in the magnitude of their impact. Therefore, the final ranking of scores was calculated in the third round of the Delphi method was used as a basis for weighting the ECIs. The goal was to help project managers understand the impact of each individual ECI better and allocate their limited resources more effectively to overcome complexity challenges; therefore, the RSW method was used to calculate the impact of each ECI in making a project complex.

4.2. Contractor stakeholder

The list of ranking and weighting associated with ECIs in aspect of contractor entity is shown in Table 3. This table illustrates that "peak number of full-time equivalent (FTE) participants on the project management team (PMT)" received the highest score of 28 and ranked as the most significant indicator in the first round Delphi method. The SMEs from contractor stakeholders agreed that a high number of FTE participants on the PMT during the early phases of a project could make the project decision-making process challenging and time-consuming. Furthermore, if the peak number of FTE participants on the PMT team is vastly greater than the average number of participants in the same group, it means that many of the team members joined the construction phase late and may not be fully aware of project issues. In order to solve this problem, a significant amount of time required to spend bringing the new participants to the same level of knowledge as the other PMT members.

As shown in Table 3, the ECI "impact of timing of the change orders" received the highest significant ECI with a score of 17 and recorded as a first rank in the second and third rounds of Delphi method in the aspect of contractor entity. The workshop experts discussed that deriving large-scale change orders can make project execution more complex and delay the construction process. The

Table 4. Identified complexity indicators corresponding to owner's perspective, ranking, and weighting of them

ECI #	Complexity Indicator	Round 1		Round 2 & 3*		Weight (%)
		Score (S_i)	Rank (R_i)	Score (S_i)	Rank (R_i)	
5	# of executive oversight entities above the PMT	25	3	22	1	13.01
21	Company's familiarity with technologies in design phase	29	2	20	2	11.83
31	Impact of magnitude of the change orders	17	8	18	3	10.65
36	Frequency of workarounds	23	5	18	3	10.65
14	Peak # of FTE on the PMT during design phase	24	4	14	4	8.28
26	Impact of project location on the project execution plan	25	3	12	5	7.10
2	Impact of required approvals from external stakeholders	22	6	11	6	6.50
32	Impact of timing of the change orders	10	13	10	7	5.91
35	Field craft labor quality issues during construction	7	15	9	8	5.32
15	Peak number of participants (FTE) on the PMT in procurement phase	0	0	7	9	4.14
4	# of joint-venture entities	31	1	7	9	4.14
10	# of total permits to be required	5	17	7	9	4.14
33	RFIs drive project design changes	0	0	4	10	2.36
11	Level of difficulty in obtaining permits	3	19	3	11	1.77
28	Project location remoteness	19	7	3	11	1.77
37	Percentage of craft labor turnover	0	0	3	11	1.77
20	Difficulty in system design and integration	2	20	1	12	0.59

Note: *As the results of rounds 2 and 3 were the same, their corresponding score and ranking values are demonstrated in one column.

SMEs believed that major changes in the project's scope or substantial design errors identified later in the project might lead to a significant amount of rework, making it very difficult for the contractor stakeholder to handle and manage its unintended consequences. If scale of the change orders is considerable and there is no prior planning for the proposed changes, procurement of the materials and availability of the skilled crafts could be major issues (Safapour, Kermanshachi, & Ramaji, 2018; Safapour & Kermanshachi, 2019).

In addition, the ECI "impact of the magnitude of the change orders" received the highest significant ECI with a score of 17 and recorded as a first rank from the perspective of contractor stakeholder. Late issuance of change orders commonly leads to the reduction in productivity, delay in completion schedule, and thus, reduction in quality of work. Additionally, late deriving change orders leads to substantial overhead costs for contractor entities. Consequently, major schedule delay and cost overrun would occur in construction projects.

4.3. Owner stakeholder

Table 4 indicates that the ECI "number of executive oversight entities above the project PMT", which was ranked by owner stakeholder as the third highest ECI with a score of 25 in the first round of Delphi method, was recorded as the most significant ECI through the second and third rounds of the Delphi method with a weight of 13.01%. The executive oversight entities help the PMT take corrective actions at the right time in mitigating any risk. Owner entity commonly assists in achieving excellence in project delivery by exploring potential hidden problems that should have been addressed. Thus, if there are an insufficient number of executive oversight entities above the PMT, a construction project might subject to the cost overruns and schedule delays.

As shown in Table 4, "company's familiarity with technologies in the design phase" was ranked as the second highest ECI by the owner entity during the second and third rounds. The score of this ECI in the aspect of the

Table 5. Identified complexity indicators corresponding to consultant's perspective, ranking, and weighting of them

ECI #	Complexity Indicator	Round 1		Round 2 & 3*		Weight (%)
		Score (S_i)	Rank (R_i)	Score (S_i)	Rank (R_i)	
14	Peak # of FTE on the PMT during design phase	15	7	20	1	11.83
21	Company's familiarity with technologies in design phase	15	7	13	2	7.69
36	Frequency of workarounds	16	6	10	3	5.91
17	Average # of FTE on the PMT during procurement phase	15	7	10	3	5.91
27	Level of infrastructure existed at the site	18	4	10	3	5.91
25	# of execution locations during fabrication	21	3	9	4	5.32
38	Percentage of craft labor sourced locally	12	10	8	5	4.73
35	Field craft labor quality issues during construction	17	5	8	5	4.73
33	RFIs drive project design changes	6	15	8	5	4.73
30	Clarity of change management process project team members	14	8	8	5	4.73
31	Impact of magnitude of the change orders	39	1	8	5	4.73
5	# of executive oversight entities above the PMT	14	8	8	5	4.73
4	# of joint-venture entities	16	6	7	6	4.14
1	Influence of this project on the organization's overall success	13	9	7	6	4.14
29	Percentage of design completed at the start of construction	5	16	7	6	4.14
26	Impact of project location on the project execution plan	14	8	6	7	3.55
32	Impact of timing of the change orders	13	9	5	8	2.95
37	Percentage of craft labor turnover	9	12	4	9	2.36
8	Specific delays or difficulties in securing project funding	0	0	4	9	2.36
22	Company's familiarity with technologies in construction phase	8	13	3	10	1.77
2	Impact of required approvals from external stakeholders	4	17	3	10	1.77
34	Quality issues of skilled field craft labor during project construction	7	14	2	11	1.18
13	Compare target project cost against industry/internal benchmarks	0	0	1	12	0.59

Note: *As the results of rounds 2 and 3 were the same, their corresponding score and ranking values are demonstrated in one column.

mentioned entity was obtained 20. The SMEs from owner stakeholder believed that if the designers/engineers do not receive adequate training and/or have insufficient knowledge and understanding of technologies involved in the design phase, the results will be incomplete drawings and/or poorly prepared project execution documents. Such deficiencies may be addressed during the constructability review period; otherwise, they will lead to major reworks during the construction phase. In these types of scenarios, the project complexity level is raised, and the efficiency of the execution process is diminished, as project logistics and schedules are affected adversely. In addition, the ECI "impact of the magnitude of the change orders" received the third highest significant ECI with a score of 18 through the second and third rounds of the Delphi method.

4.4. Consultant stakeholder

Table 5 indicates that the "peak number of FTE participants on the project management team (PMT) during detailed engineering/design phase of the project" received a score of 15 in the first round. The score of this ECI increased in the second and third rounds and was recorded as the highest significant ECI with a score of 20. The SMEs from consultant entities believed that a high number of FTE participants on the PMT during the early phases of a project could make the project decision-making process challenging and time-consuming. Furthermore, if the peak number of FTE participants on the PMT team is vastly greater than the average number of participants in the same group, it means that many of the team members joined the design/engineering phase late and may not be fully aware of project concerns, problems, and design criteria. To solve this problem, a significant amount of time should be spent bringing the new participants to the same level of knowledge as the other PMT members. Otherwise, the new members' lack of knowledge could cause inefficiencies, disagreements, and conflicts. In both cases, the project outcome could suffer and the impact may affect the project schedule, quality, and cost. Therefore, this study suggests that project managers need to hire full-time PMT members early in the engineering/design phase and try to avoid staffing changes.

Furthermore, the ECI "company's familiarity with technologies in design phase" received the second highest significant ECI with a score of 13 in the second and third rounds of the Delphi method. The SMEs from consultant entities strongly believed that if the designers have insufficient knowledge of using new technologies involved in the design phase, many design changes and rework could derive in the project. Moreover, "Frequency of workarounds" received the third highest score of 10.

4.5. Identification of shared ECIs

In this section, the overlap ECIs which were selected by all three stakeholders, are investigated and analyzed. These overlap ECIs would make a project complex in the aspect of all primary stakeholders. The stated results are presented in Figure 3. This figure shows that out of the 38

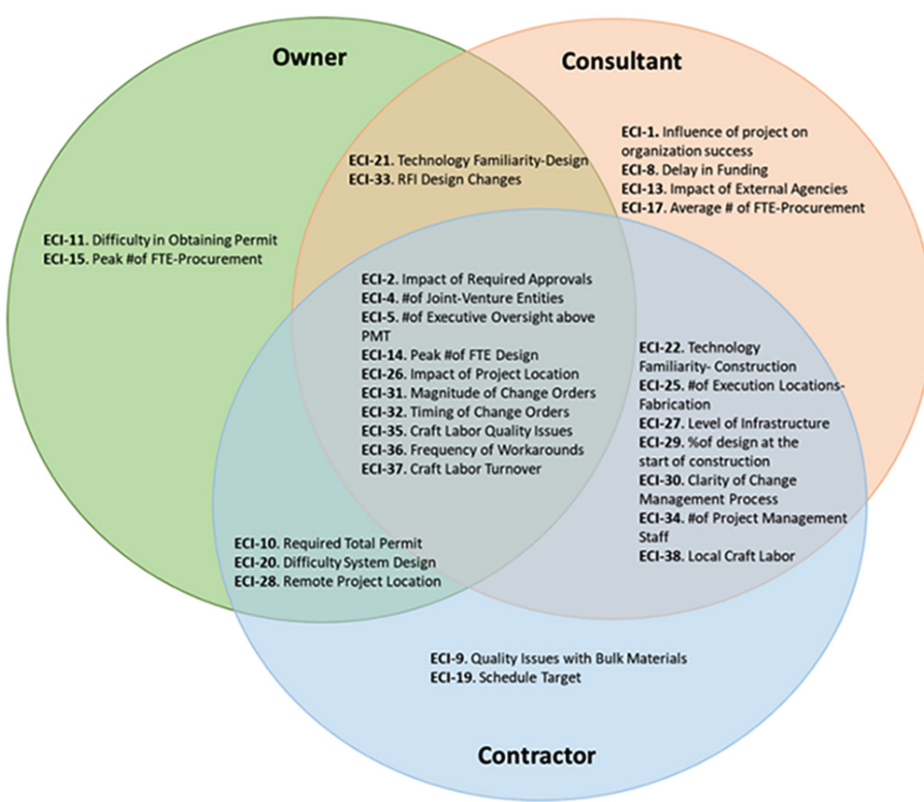

Figure 3. Entity-based complexity indicators and their overlaps

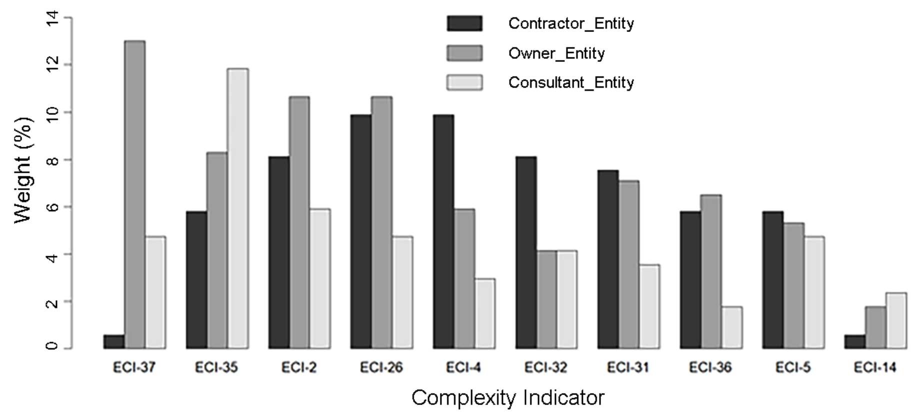

Figure 4. Comparison of the weights associated with the shared ECIs among primary project stakeholders

entity-based complexity indicators, 10 of them were found shared and overlap ECIs. In other words, these 10 overlap ECIs make a construction project complex from the perspectives of all primary stakeholders. The shared ECIs that were selected by all of the stakeholders were magnitude of change orders, frequency of workarounds, peak number of FTE participants involved in the design phase, number of executive oversight above PMT, impact of project location, impact of required approvals, timing of change orders, craft labor quality issues, number of joint-venture entities, and craft labor turnover.

Figure 4 illustrates that the impact of the project location on the execution process (ECI-26) is one of the shared complexity indicators, which affects the performance of all of the primary stakeholders. New geographic regions could increase the complexity of the design, procurement, and execution of construction projects due to lack of familiarity with and/or extreme climates; logistical changes required for some field activities; design complications with respect to safety and security; unavailability of vendors and specialized subcontractors; language and cultural differences in international projects; and first-time settlement of project requirements such as field staff and regional office (Safapour, Kermanshachi, Shane, & Anderson, 2017).

Required excessive approvals in a construction project (ECI-2) are commonly out of control of the project entities and make a construction project more complex, so these approvals may have a negative impact on projects performance. Three primary stakeholders should make great efforts to create a friendly environment in which the duration of the approval procedure is shortened and the bureaucracy in the system decreases. Therefore, project stakeholders should try to adopt the strategies to have an effective communication with external stakeholders.

Figure 4 portrays the comparison of the weights corresponding to each of the shared ECIs. As shown in this figure, among these shared complexity indicators, the following four ECIs received the maximum weights by contractor entities: timing of change orders, number of joint-venture partners, the impact of project location, and craft labor quality issues.

The SMEs from contractor entities believed that participating in several numbers of joint venture partners in a project (ECI-4) might have negative impact on projects performance because the objectives of joint venture partners are commonly vague. Additionally, joint venture partners hardly communicate clearly with contractor stakeholders. In addition, the flexibility of contractor stakeholder may be restricted in a construction project with joint venture entities.

Four of the 10 shared ECIs received the highest weights from the perspective of owner entity. Figure 4 shows that these four indicators were "craft labor turnover (ECI-37)", "frequency of workarounds (ECI-36)", "impact of location of a project (ECI-31)", and "impact of required approvals (ECI-2)". Additionally, this figure illustrates that among the 10 shared complexity indicators, "number of executive oversight entities among the PMT" became the most significant indicators with a weight of 13.01% from the perspective of owner entity. Among these ECIs, the third highest weight was recorded by owner entity for ECI-36 (company's familiarity with technology in design phase) and ECI-31 (impact of the magnitude of the change orders) with the same weights of 10.65%.

In terms of the consultant entities' perspective, "peak number of FTE member in the design phase (ECI-14)" and "craft labor quality issues (ECI-35)" received the highest weights. ECI-14 received the second highest weight among the 10 shared ECIs with a weight of 11.83% by consultant stakeholder.

4.6. Comparison of entity-based weighting of complexity categories

The authors analyzed and compared the weight of each complexity category, shown in Figure 1 and Table 2, in aspect of the primary stakeholders. For this purpose, the weight corresponding to each of the 11 complexity categories associated with three primary stakeholders were

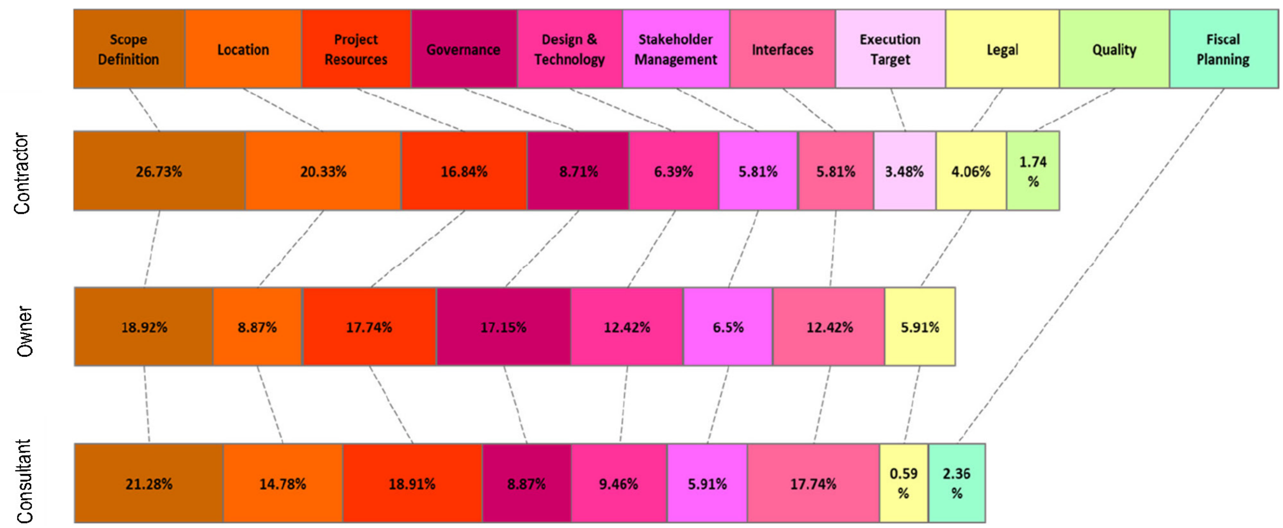

Figure 5. Comparison of entity-based weighting of complexity categories

calculated and shown in Figure 5. In order to calculate the weight of each category, the weight of ECIs belonged to the corresponding complexity category was combined into aggregate. Figure 5 illustrates that the complexity category "scope definition" was recorded as the most significant category by contractor entity with a weight of 26.73%. To explain in detail how this weight was computed, it is stated that category of "scope definition" consists of ECI-29, ECI-30, ECI-31, ECI-32, and ECI-33. The associated weights of these ECIs by owner stakeholder were summed up and recorded a total weight of 26.73%. The SMEs widely accepted that the challenges associated with scope definition affect projects' performance negatively. If the scope of a project is vague until the beginning of the construction phase and/or if the scope of a project has not been defined well during the design phase unnecessary rework might occur. Accordingly, the contractor entity has to spend excessive time and cost to meet the requirements of the owner entity and/or customer. So, schedule delays and cost overruns would be unavoidable.

With respect to complexity category "project resources", the SMEs strongly agreed that the advanced planning should be made to make sure that the required materials could be delivered at the appropriate time. Unavailability of material, equipment, and machinery at the needed time and/or lack of sufficient financial resources cause major schedule delays. For instance, if the materials are delivered too early, it will be difficult to store them securely. On the contrary, if the materials are delivered too late, the project will subject to schedule delays. This category (project resources) received the highest weight (18.91%) by consultant entity.

Moreover, the SMEs from owner stakeholders strongly believed that the complexity category "governance" has the negative impact on projects performance. The weight of governance category associated with the aspect of owner entity was calculated as 17.15%. The ECIs of the mentioned category normally issue the challenges associated with restriction of flexibility for projects participants, unclear and unrealistic projects' aim, and lack of effective communication among projects' parties. Therefore, the governance issues could result in the delay in completion of schedule, reduction in productivity and quality of work, holding on work in other areas, and issuance of rework in construction projects.

5. Case study implementation and analysis

To evaluate the implementation results of the entity-based weighting, the research team selected three US case study projects (Project 1, Project 2, and Project 3) in order to calculate the entity-based complexity levels and assess the differences among three stated projects. The breakdown of information of the mentioned case study projects is shown in Table 6.

Table 6 illustrates that all of the case studies belonged to US heavy industrial projects. The scope of the first project was the installation of gas-fired combustion tur-

Table 6. Breakdown of information of three case study projects used for implementation and analysis of results

Project	Type of project	Project scope	Baseline budget	Baseline schedule
1	Heavy industrial	Installation of gas-fired combustion turbines and heat recovery steam generators and steam turbines	$74 M	36 months
2	Heavy industrial	Chemical manufacturing expansion	$56 M	27 months
3	Heavy industrial	Co-generation power plant	$86 M	42 months

bine, heat recovery steam generator, and steam turbine. The scope of the second project was the chemical manufacturing expansion. Additionally, the scope of the third case study project was the co-generation power plant. The baseline budget for case studies 1, 2, and 3 were $74 million, $56 million, and $86 million, respectively. Moreover, the baseline schedule for case studies 1, 2, and 3 were 36 months, 27 months, and 42 months, respectively.

A survey was developed in the form of an Excel sheet in order to evaluate the complexity level of the three case study projects in the aspect of primary stakeholders. Additionally, the entity-based weightings of ECIs, which were recorded and presented in Tables 3, 4 and 5, were provided in the survey. Then, the survey was sent to the practitioners who evaluated the complexity of the stated case studies.

As stated earlier, the score of each ECI represents the contribution of that indicator to the complexity of a project at the time of assessment. According to the project team decision, the level of impact for each ECI received the score of "0" (if the indicator is not applicable to the project at this point) or received the score of "9" (if the indicator greatly contributed to the overall complexity of project at this point). To calculate the weight of each ECI in the aspect of primary stakeholders, the score of each ECI was multiplied by the corresponding weight. The calculated weights are illustrated in Table 7. This table consists of three sections that each section has three columns presenting the complexity weights of ECIs based on owner, contractor, and consultant perspectives. The first, second, and third sections of Table 7 shows the weight of ECIs associated with the first, second, and third case study projects (Project 1, Project 2, and Project 3) from the perspective of three primary entities. It is demonstrated that the entity-based weights associated with Project 1 and Project 3 from three primary stakeholders are approximately similar to each other.

Table 7 shows that in Project 1, "impact of required approvals from external stakeholders" and "impact of project location" received the considerable weights from perspective of owner compared to consultant and contractor entities. "Impact of timing of the change orders" and "impact of project location" received the highest weights from contractor entity among all primary stakeholders.

In Project 2, "peak number of full-time equivalent on the project management team during design phase" from perspective of consultant entity received substantial weight compared to other primary stakeholders. Additionally, "level of infrastructure existed at the site" was obtained the same weights for both consultant and contractor entities.

As illustrated in Table 7, in Project 3, "impact of magnitude of change orders" received the highest weight from perspective of owner entity compared to other primary stakeholders. In addition, "project location remoteness" was obtained considerable weight for contractor entity.

As stated earlier, the total weight associated with each complexity category is obtained by summation of the ECIs' weight, which belongs to the corresponding com-

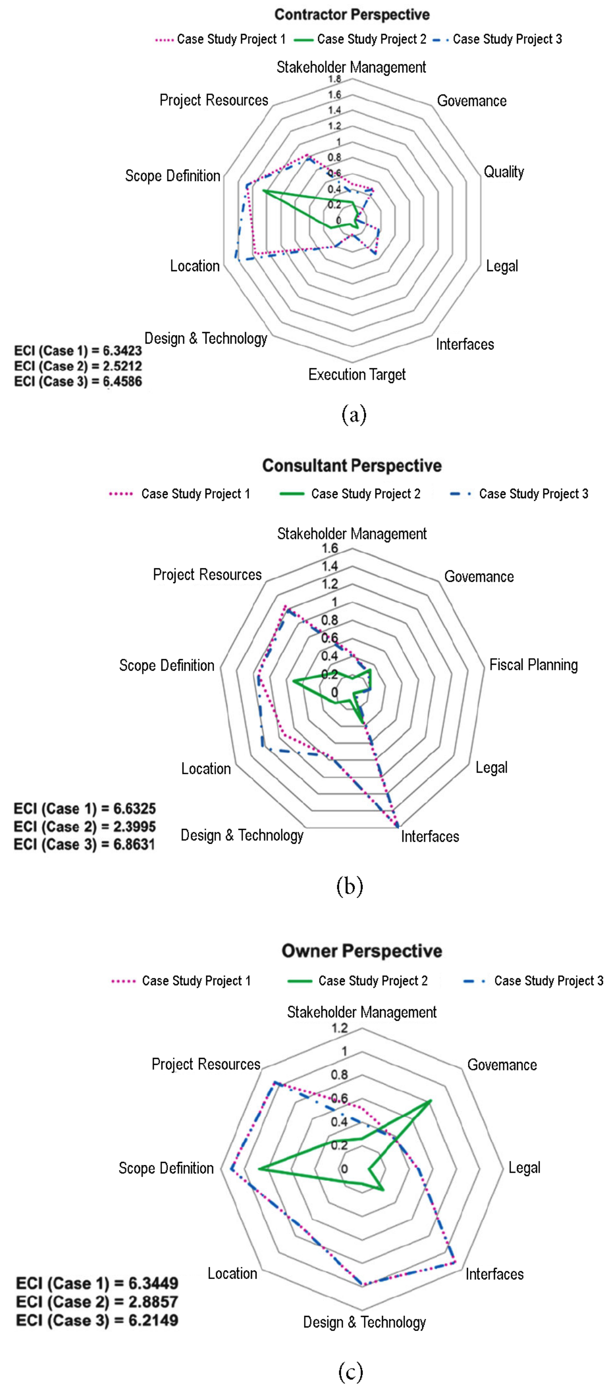

Figure 6. Comparison of weighting of complexity categories in aspect of three primary stakeholders associated with three case study projects: (a) Contractor perspective, (b) Consultant perspective, (c) Owner perspective

plexity category. Then, by adding up all ECIs' weight associated with each case study, the total weight of a project is obtained. Accordingly, the total weight of ECIs in the aspect of contractor entity ranges between 0 and 8.991. From the perspective of the owner entity, the total weight of ECIs ranges from 0 to 8.9937. Additionally, the mentioned weight in the aspect of the consultant entity ranges between 0 and 8.991. So, as illustrated in Figures 6(a)

Table 7. Comparison of weighting of complexity indicators in the aspect of primary stakeholders associated with three case study projects

Category	# ECI	Project 1 – weight (%)			Project 2 – weight (%)			Project 3 – weight (%)		
		Consultant	Contractor	Owner	Consultant	Contractor	Owner	Consultant	Contractor	Owner
Stakeholder management	ECI-1. Influence of this project on the organization's success	0.28			0.08			0.28		
	ECI-2. Impact of required approvals from external stakeholders	0.14	0.46	0.52	0.07	0.23	0.26	0.1	0.34	0.39
Governance	ECI-4. # of joint-venture entities	0.24	0.48	0.24	0.04	0.08	0.04	0.24	0.48	0.24
	ECI-5. # of executive oversight entities above the PMT	0.04	0.01	0.13	0.28	0.03	0.78	0.04	0.01	0.13
Fiscal planning	ECI-8. Specific delays or difficulties in securing project funding	0.21			0.21			0.21		
Quality	ECI-9. Quality of bulk materials during project execution		0.05			0.03			0.05	
Legal	ECI-10. # of total permits to be required		0.36	0.37		0.04	0.04		0.36	0.37
	ECI-11. Level of difficulty in obtaining permits			0.1			0.01			0.1
	ECI-13. Compare target project cost against industry benchmarks	0.02			0.01			0.05		
Interfaces	ECI-14. Peak # of FTE on the PMT during design	1.06	0.52	0.74	0.23	0.11	0.16	1.06	0.52	0.74
	ECI-15. Peak # of FTE on the PMT in procurement			0.37			0.08			0.37
	ECI-17. Average # of FTE on the PMT during procurement	0.53			0.11			0.53		
Execution target	ECI-19. Schedule targets compared to industry benchmarks		0.17			0.06			0.17	
Design & technology	ECI-20. Difficulty in system design and integration		0.31	0.03		0.05	0.01		0.31	0.03
	ECI-21. Company's familiarity with technologies in design	0.61		0.94	0.07		0.11	0.61		0.94
	ECI-22. Company's familiarity with technologies in constr.	0.14	0.09		0.01	0.01		0.14	0.09	
Location	ECI-25. # of execution locations during fabrication	0.47	0.2		0.1	0.04		0.47	0.2	
	ECI-26. Impact of project location	0.28	0.6	0.56	0.07	0.15	0.14	0.28	0.6	0.56
	ECI-27. Level of infrastructure existed at the site	0.17	0.17		0.05	0.05		0.47	0.46	
	ECI-28. Project location remoteness		0.37	0.14		0.04	0.01		0.37	0.14
Scope definition	ECI-29. % of design completed at the start of constr.	0.24	0.03		0.04	0.01		0.24	0.03	
	ECI-30. Clarity of change management	0.18	0.25		0.18	0.25		0.18	0.25	
	ECI-31. Impact of magnitude of the change orders	0.28	0.59	0.63	0.23	0.49	0.53	0.28	0.59	0.63
	ECI-32. Impact of timing of the change orders	0.17	0.59	0.35	0.14	0.49	0.29	0.17	0.59	0.35
	ECI-33. RFIs drive project design changes	0.23		0.11	0.09		0.04	0.23		0.11
Project resources	ECI-34. Quality issues of craft labor during construction	0.09	0.09		0.01	0.01		0.03	0.03	
	ECI-35. Field craft labor quality issues during construction	0.18	0.23	0.21	0.09	0.11	0.1	0.18	0.23	0.21
	ECI-36. Frequency of workarounds	0.41	0.56	0.74	0.11	0.16	0.21	0.41	0.56	0.74
	ECI-37. Percentage of craft labor turnover	0.11	0.02	0.08	0.02	0.01	0.01	0.11	0.02	0.08
	ECI-38. Percentage of craft labor sourced locally	0.42	0.1		0.04	0.01		0.42	0.1	

and 6(b), from the perspective of contractor and consultant stakeholders, case study 3 showed the higher degree of complexity compared to case studies 1 and 2 [ECI (Case 3) > ECI (Case 1) > ECI (Case 2)]. Furthermore, Figure 6(c) shows that in the aspect of owner aspect, case study 1 received the higher degree of complexity compared to case studies 2 and 3 [ECI (Case 1) > ECI (Case 3) > ECI (Case 2)].

Conclusions

The intent of this study was to identify, rank and weight project complexity indicators based on the perspective of three primary stakeholders in US construction projects. Additionally, the entity-based weighting of complexity categories, as well as shared ECIs, were determined. The hierarchical ranking of ECIs and their weight enable owners, contractors, and consultants to approach project planning and execution more precisely and wisely. Although previous researchers have focused on complexity indicators and their levels of impact, none of them has identified, ranked and weighted the project complexity indicators according to the primary stakeholders' perspective associated with the U.S. construction projects. The aggregated results demonstrated that the top complexity indicators in the aspect of the contractor, owner, and consultant stakeholders are "the impact of magnitude of change orders," "number of executive oversight entities above the PMT", and "the peak number of FTE participants on the PMT during the design phase", respectively. All of the primary stakeholders agreed that timing of change orders, magnitude of change orders, frequency of workarounds, craft labor turnover and peak number of project participants in design phase, craft labor quality issues, impact of required approvals, and number of executive oversight entities above project management team have significant impacts on the complexity of a project. In addition, as new geographic regions could increase the complexity of a project due to lack of familiarity with climates as well as logistical changes needed for some field activities, the ECI "impact of project location" was recorded as a shared ECI in the aspect of primary stakeholders. Moreover, "required excessive approvals in a construction project" is normally out of control of the project entities and consequently makes a project more complex. So the mentioned ECI was recorded as a shared ECI. This study also concluded that "scope definition" and "project resources" are the top two complexity categories, which play critical roles in making a construction project more complex in the aspect of three primary stakeholders. The outcomes of this study can be utilized by primary stakeholders to develop a complexity assessment and management model, which would enable industry practitioners to effectively allocate resources in complex projects of construction projects. Although this study was conducted based on the complexity in US construction projects, it would be a helpful guidance for practitioners worldwide to use the results of this study. Moreover, this study would assist the practitioners in making the appropriate modifications according to the physical and/or other characteristics of their construction projects.

Although the authors of this study made a considerable effort to provide valid and reliable results, our study contains some limitations. First, this study completely relied on Delphi technique. This method generates results based on the understanding and experience of a limited number of participants. As discussed in the section of "Delphi method", all of the panelists were carefully selected in order to be qualified and experienced in the construction industry. These panelists assisted in increasing the quality of responses; however, the impacts of subjectivity and biases in responses could not be completely ruled out. Second, this study relied on the construction industry associated with US projects. Although this study made the basis for identifying and assessing project complexity in international projects considering their physical and other characteristics, this study lacks the cross-professional, cross-organizational, and cross-national study from experts worldwide.

Furthermore, this study adopted the Delphi technique to identify, weight, and rank the entity-based complexity indicators, which would be the basis for the future researches. Future studies could employ different research methods such as case study projects, interviews, and survey to examine the identified results of the current study. Additionally, a set of complexity management strategies could be developed for each of the primary stakeholders. Accordingly, each complexity indicator would have multiple management strategies mitigating the undesired consequences of project complexity. Similarly, a decision-making tool could be developed to accurately quantify and assess the level of entity-based complexity and facilitate project complexity management activities.

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