Managing Interfaces in Large-scale Projects: The Roles of Formal Governance and Partnering

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Abstract

Interface management has been viewed as one of the important organizational capabilities to promote coordination and integration among stakeholders in construction project delivery, especially for large-scale projects. This paper examines the role of formal governance, partnering, and the nature of the boundary activities and their interactions in the interface management performance outcomes. To achieve this goal, an integrated framework with consideration of the influence of formal governance, partnering, and boundary activities on interface management performance and associated project outcomes was developed and the framework predictions were empirically tested by using the data collected from 85 international large-scale projects. The results show that formal governance is the one of dominant determinants of interface management performance, which can influence the management outcomes improving partnering and boundary activities. Partnering and boundary activities are also significant antecedents of interface management performance, which in turn improves project outcomes of large-scale construction projects. Formal governance and partnering mutually reinforce each other. Interface management performance is positively corelated to project outcomes in terms of quality, cost, and schedule. The present empirical research contributes to the fundamental understanding of the critical factors that govern the interface management

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performance, ultimately the project outcomes. In addition, the outcomes of this study highlighted the broad managerial implications for project participants in large-scale projects.

Keywords: Project management; Interface management; Governance; Partnering; Boundary activities; coordination.

Introduction

Recent years have seen a growing importance in studying large-scale projects in the field of construction management because of their unique characteristics and strategic values (Flyvbjerg 2014). A large-scale construction project is usually described as a project that is characterized by its physical size, long duration, massive investment, high complexity and uncertainty, a wide range of stakeholders, significant social and economic impacts, and dynamic interfaces (Floricel and Miller 2001; Li et al. 2018). Large-scale construction projects consist of distinct but interdependent activities that are handled by a range of specialized organizations (e.g., subcontractors). As a result of this distribution (and sometimes fragmentation) in roles, numerous interfaces are generated (Healy 1997). Specifically, following the definition of Wren (1967), the concept of the interface in the construction industry refers to "the common boundaries between independent but interacting systems, organizations, project phases, and construction elements". Obviously, interfaces abound in a construction project and each of them can be a risk to the project if it is mismanaged (Shokri et al. 2016). It is widely acknowledged that interface issues such as miscommunication between parties and the inability of project stakeholders to work coordinately can lead to delays and require rework to achieve the specified quality (Shokri et al. 2015). The dynamic, temporary, and interdisciplinary in nature of construction projects makes managing these interdependent interfaces a significant challenge for project participants.

To address the challenges above, there has been an increasing interest in using interface management (IM) to enhance coordination and alignment among stakeholders (Shen et al. 2018a). As a critical organizational capability, interface management is described as the process of managing the boundaries between interacting systems, phases, and organizations (CII 2014). The success of large-scale projects requires collaboration and a working harmony between all project stakeholders (e.g., designers, suppliers, consultants, contractors, and subcontractors), which makes IM even more significant in managing the complex and dynamic interfaces among these project stakeholders (Shokri et al. 2015).

Past IM studies have focused on formal governance to improve IM implementation, which is defined as a collection of formal principles, standardized procedures, and management tools to govern interfaces (Shen et al. 2018; Shokri et al. 2015). The purpose of such efforts is to allow interface stakeholders to communicate and coordinate in a consistent way, thereby reducing uncertainty and ambiguity. However, such formal governance is often insufficient in reality as many IM activities are unpredictable and cannot be standardized in advance. Under such a situation, partnering, which can be understood as a win-win relationship between participants, has been considered as a complementary and even more effective way to reduce interface issues since it can provide the possibility of achieving a high degree of common goal and integration among organizations (Bresnen and Marshall 2000). By developing a long-term commitment and win-win relationship among project stakeholders, partnering drives them to cooperatively work as a team disregarding organizational boundaries (Tang et al. 2006).

Although researchers have suggested the significant roles of formal governance and partnering in project management (Ahola et al. 2014), they have paid little attention to how these two mechanisms collectively influence IM performance, which refers to efficiency and effectiveness of interface task accomplishment, and the accuracy of information exchange (CII, 2014). In addition, in the context of large-scale construction projects, it remains unexplored that how the IM performance influences overall project outcomes including schedules, cost, and quality. Thus, this research aims to examine the effects of formal governance and partnering on IM performance, thereby providing the mechanism for improving project outcomes of large-scale construction projects. An in-depth understanding of the key factors for managing interfaces is important since it can provide the basis for choosing effective approaches to efficiently enhance the flows of information and resources use.

Theoretical Background and Hypotheses

A theoretical model is proposed to investigate the relationships among formal governance, partnering, boundary activities, IM performance, and project outcomes in large-scale projects, as displayed in Fig. 1. The detailed explanations of the research hypotheses are elaborated in this section.

[Insert Fig 1 here]

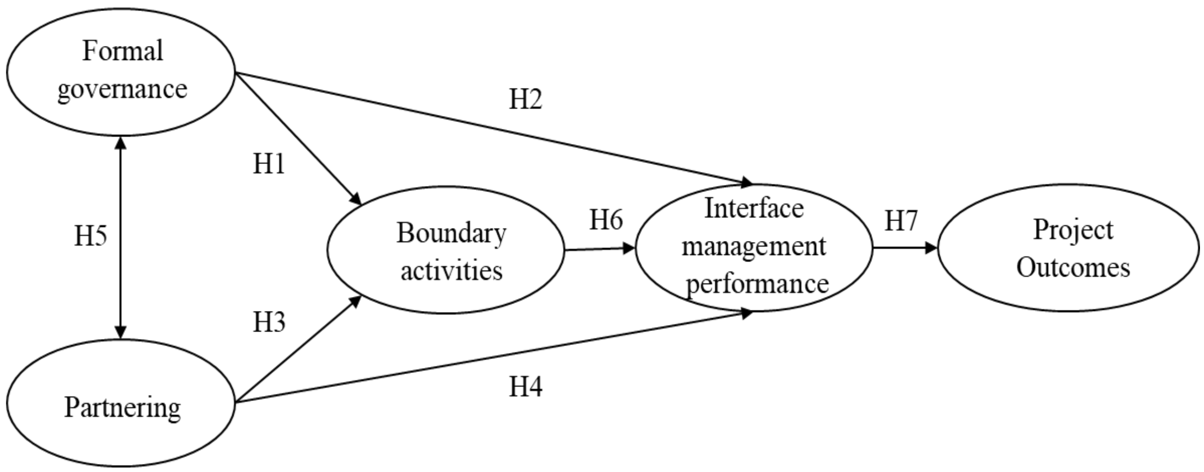


Fig. 1. Conceptual interface management framework

The Role of Formal Governance in IM

Formal governance in this study is defined as “a set of formal principles, structures, and processes for the undertaking and management of projects” (Crawford and Cooke-Davies 2009). Broadly speaking, formal governance has been viewed in two ways in the literature. One considered it as “external to any specific project” and focuses on specifying standards and regulations, which can be generalized to most individual projects to comply with (Ahola et al. 2014). Another view is that it is “internal to a specific project” - focuses more on inter-organizational relationships (Ahola et al. 2014; PMI 2017). Instead of standardization, this view assumes that every project is unique, which needs to be governed in a tailored and specific manner with an open view (Artto and Kujala 2008). Fundamentally, formal governance aims to balance the interests and responsibilities of different stakeholders through providing a framework for project-wide managerial actions (Biesenthal and Wilden 2014). Formal governance specifically employs principles for aligning goals, directing and controlling the organization, and specifying stakeholders' responsibilities and rights (Müller 2009). It aims to develop a shared set of procedures and contractual arrangements for all project stakeholders to follow (Ruuska et al. 2009). Formal governance of large-scale construction projects involves the development of a set of principles, responsibilities, processes, and structures (Müller et al. 2016). In construction, formal governance pertaining to IM encompasses work breakdown structure, contractual control, standard IM procedures and rules, and particular organizational structure (e.g., position) (CII 2014; Ahn et al. 2016; Shokri et al. 2016; Lin 2013). Despite the significance of managing dynamic interfaces in large-scale construction projects, it is very challenging for project managers to complete interfacing tasks because it requires strong coordinating skills to cope with various project stakeholders with different professions and interests (CII, 2014). Because IM is a relatively new management approach to most project practitioners (Chen et al. 2008), their understanding and practice of IM vary, which may affect the effectiveness of IM implementation (Ahn et al. 2016). The establishment of specified standards, routines, and regulations of IM can facilitate project participants to reach a mutual understanding of their roles and responsibility on the interface tasks, which thereby reduce the variances of their' behaviors across organizational boundaries (Shen et al. 2018b). As such, they are likely to perceive fewer difficulties in performing boundary behaviors, which encourage them to share information and collaborate with others across the organizational boundaries (Bandura 1986).

It was found that the components of *formal governance (e.g.,* standardized procedure) are the key drivers for interface participants' behaviors (Shen et al. 2018a). With clear standardized procedures and rules, uncertainty and ambiguity from the inter-organizational interactions are likely to be reduced, and consequently (Bidwell 2012), boundary activities such as defining and shaping the boundary, collecting and exchanging information are expected to be smoother. Therefore, we proposed the following:

H1: *Formal governance has a positive effect on boundary activities.*

Effective formal governance can support the success of IM by providing a structure that defines the work scope and directs project participants' efforts and by reinforcing their' boundary-spanning responsibilities (Marrone et al. 2007). With standardized workflows and a common understanding of how to work together in interdependent tasks, the collective actions at interfaces would tend to be more predictable, which will encourage effective information transformation and coordination (Joslin and Müller 2016). In addition, appropriate formal governance can reduce information asymmetry, which thereby reduces inter-firm coordination costs and transaction costs (Williamson 1979). It was suggested that formal governance can contribute to managing interfaces effectively (Pavitt and Gibb 2003). Therefore, the authors proposed the following:

H2: *Formal governance has a positive impact on IM performance.*

The Role of Partnering in Interface Management

Although formal governance plays a critical role in driving interactions across organizational boundaries (Biesenthal and Wilden 2014; Müller et al. 2016), many issues such as poor coordination and adversarial relationships between parties still commonly arise from large-scale projects because the goals and interests of project stakeholders are not aligned with each other (Tang et al. 2006). Hence, the success of large-scale projects also requires another type of governance – relational governance (Cao and Lumineau 2015).

Partnering, as a form of relational governance, is an emerging strategy with the attempts to generating a win/win attitude among all parties and change the adversarial situation (CII 1991; Cheng and Li 2002).

Partnering encompasses critical components such as commitment, mutual goals, attitude, commitments, trust, and communications and the heart of partnering is trust (Cheng and Li 2002). As trust-based partnering is developed between two organizations, their boundaries will tend to be more permeable, which encouraging active inter-organizational boundary activities such as communicating design issues with outsiders, obtaining feedbacks, coordinating, and negotiating (Shen et al. 2017). For example, the procurement costs of materials and equipment account for a large proportion of the total cost of large-scale construction projects (e.g., hydropower projects). Establishing long-term partnering relationship with major suppliers becomes a common practice of many contractors because, for the contractors, this win-win solution enables stable supplies of the needed resource for construction and ensures more reasonable prices, which is critical to mitigate logistical uncertainties and reduce procurement cost (Azambuja et al. 2014). For the suppliers, partnering with the contractors can help them access more markets.

In a climate of trust and cooperation, project stakeholders tend to voluntarily share knowledge and extra information across the organizational boundary, as well as work cooperatively towards their shared goals (Cheng and Li 2002). Building communication protocol and strengthening relationships with other stakeholders are also influential to facilitate boundary-spanning activities (Du and Pan 2013; Marrone et al. 2007). Thus, the authors hypothesized that:

H3: *Partnering has a positive effect on boundary activities.*

Partnering is likely to be a pivotal factor in improving IM. In prior research, trust, openness, and communication, which are the key components of partnering, are highlighted as the critical factors in improving inter-organizational IM performance (Shen et al. 2017). First, partnering is essentially a trust-based relationship. Researchers have widely acknowledged that many inter-organizational cooperative behaviors (e.g., teamwork and interpersonal cooperation) can be driven by the mutual trust (Jones and George 1998). This kind of favorable attitude supports interactions between people and encourages members from different groups to spontaneously work as a team (Jones and George 1998). Despite the existence of organizational boundaries, mutual trust can promote organizational flexibility and enhance the quality of information exchange (Kadefors 2004).

Second, communication has been recognized as an essential factor in successfully managing interfaces in construction projects (Chen et al. 2008; CII, 2014). Almost all activities in managing interfaces (including task-related interactions and social interactions) require communication at different levels. Thus, the authors proposed that:

H4: *Partnering has a positive effect on IM performance.*

Partnering and relational governance shared the core elements (e.g., shared vision, trust, cooperation, and long-term commitments) (Cao and Lumineau 2015). The understanding of how relational and contractual governance interplay has remained inconsistent and conditional in the literature (Zheng et al. 2008). Some scholars claim the relationship between them is complementary (Benítez-Ávila et al. 2018; Ryall and Sampson 2009; Li et al. 2010). Other researchers, however, assert that relational governance and contractual governance substitute each other (Lui and Ngo 2004). According to a meta-analysis of contractual-relational governance relationships across 149 empirical research, more extant literature supports that they complement each other (Cao and Lumineau 2015).

The basic tenet in the complementary relationships rooted in the assumption that the combination of contractual governance and relational governance can enhance the quality of governance system as they can overcome the shortfalls of one another. For example, relational governance can add more flexibility to the projects that contracts cannot provide (Floricel and Miller 2001). However, in addition to complementary and substitutive relationships, we argue that contractual governance and relational governance can also have the third relationship – mutually reinforce each other (i.e., they are positively associated with each other), instead of simply adding extra element to the governance system. Contracts with clearly defined duties and rights, fair risk allocation, as well as the punishment for the breach of contract can increase the confidence of the contracting parties in their cooperation and provide formal assurance for developing relational governance (Li et al. 2010; Bresnen and Marshall 2000). Meanwhile, organizations with partnering mindsets would automatically share extra critical information with each other without worrying the other party takes advantage of it for opportunistic behaviors, which creates more values beyond the contracts (Tang et al. 2006). Better relational governance can create and maintain the "win-win" climate among parties, which in turn facilitate better execution of the contracts during the project delivery process (Cheng and Li 2002). Therefore, this research assumed that:

H5: *Formal governance and partnering are positively correlated with each other.*

The Role of Boundary Activities in IM

An organization is not an island but relies on other organizations' inputs to maintain functioning, during which it must engage in a set of activities across their organizational boundary (Du and Pan 2013). Based on boundary theories (Ancona and Caldwell 1990; Drach-Zahavy and Somech 2010) and the characteristics of construction projects, boundary activities in IM are defined as sets of actions: 1) *acquiring resources*, which is about obtaining information and other resources outside the organization in order to complete interfacing tasks. For instance, contractors need to collect technical drawings or information from designers, and enquire prices from potential suppliers; 2) *informing*, which are related to keep other external organizations or groups informed of the organization or group's activities and progress. For example, as construction projects are constitutive of enormous distinct activities, the interdependent relationships between the inputs and outputs of these activities require designers and contractors to exchange and update technical information such as technical standards and drawings with one another promptly to enable the accuracy and consistency of information (Tang et al. 2006); 3) *coordinating and negotiating*, which refers to interactions aimed at handling technical or design problems, such as communicating design issues with outsiders and obtaining feedbacks, coordinating and negotiating with others. The execution of construction projects, for instance, is subject to changes over time due to the uncertain and demanding environment, which requires a set of exact coordination and shifts in skills or knowledge for accomplishing tasks (Faraj and Xiao 2006). It is noted that, although a lot of boundary activities can lead to the improvement of IM, this research focuses on specific activities that are formal and have a direct impact on IM outcomes.

Clearly, achieved desired IM performance requires a set of boundary activities performed jointly by project participants (CII 2014). Boundary activities could be an important mediator process for interface task accomplishment. Since large-scale construction projects require large teams with different professions, expertise and knowledge are implicitly dispersed among team members in different organizations, it is difficult to quickly locate and coordinate the "right" person who has the skill or knowledge when it is needed (Faraj and Xiao 2006). With the effective implementation of IM, frequent and timely cross-boundary communication creates more chances to accurately link the distributed expertise, which can engage project participants in the identification of inter-firm issues and result in efficient decision-making.

Existing studies report that smooth boundary-spanning activities among key project stakeholders are essential to achieve high performance (Ancona and Caldwell 1990; Marrone et al. 2007). For instance, teams undertaking extensive boundary-spanning activities were better able to manage expectations from the top management, obtain outside information and resource, and buffer external pressures (Ancona and Caldwell 1990). The more adequate boundary activities, the more they understand each other's needs and behavior patterns, the more likely to prevent potential interface problems (Shen et al. 2018a).

Thus, we proposed that:

H6: *Boundary activities have a positive effect on IM performance.*

As explained above, formal governance and partnering are hypothesized to have impacts on boundary activities, which can help to access critical resources to accomplish interface tasks (i.e., H1 and H3). Formal governance and partnering can also improve IM performance and it is likely that this happens through the mediating effects of boundary activities (facilitating inter-organizational interactions between stakeholders).

The Role of Interface Management in Project Outcomes

Empirical research has highlighted that opportunism, unclear project definitions, and external risks are the main causes of contractors' disputes and claims (Shen et al. 2017). Opportunism, which is regarded as behaviors that seek for self-interest（Williamson 1979）, is found to be common in construction industry (Wood et al. 2001). For example, some owners pushed contractors by setting unrealistic timelines or unreasonable conditions in the contracts while some contractors intended to make more profits by submitting claims (Wood et al. 2001). Partnering, therefore, is critical and needed to reduce such opportunism and mitigate external risks by encouraging stakeholders to trust, and openly share information with each other in IM, thereby reducing disputes and enhancing project outcomes.

Unclear project definitions in work scope and technical specifications might also cause disputes between stakeholders as each party has different and even conflicting conceptions about the requirements and the priority of task interdependencies (Gerwin 2004). These misalignments can yield incompatibility of efforts in IM (Gulati et al. 2012), especially when facing unexpected external risks, which consequently lead to disputes of IM and coordination failure. Ambiguous project definitions are often rooted in cognitive limitations, which refer to individuals' inability to fully recognize the interdependence among tasks, roles, and groups (Simon and March 1993). Given the bounded rationality, people often only focus on their own tasks and roles but often underestimate the interdependence between tasks and groups and the needs for coordination (Puranam et al. 2012). Through clarifying the division of works and formalizing inter-organizational activities, formal governance in IM such as developing standardized procedures mitigates the impacts of individuals' cognitive limitations (Gulati and Singh 1998) and avoid the potential for disputes in IM in dealing with external risks arising from natural and socio-economic environments, which improve project outcomes.

It is suggested that successfully implementing IM can enhance project outcomes by improving mutual understanding of the coordination needs and aligning the goals among stakeholders. For example, the inadequate or incorrect design is a common cause of the incidence of safety issues, work backlogs, cost overrun, and delays and it is mainly because that the designers and contractors did not have open communication at the early stage to clarify clients' intentions and discuss constructability of the design (Tang et al. 2013). Empirical studies also prove that projects that applied systematic IM have less cost overrun than those without implementing IM as it can reduce unwanted design iteration and reworks, which are often expensive and incur delay (CII 2014; Shokri et al. 2015).

Therefore, we proposed that:

H7: IM performance has a positive effect on project outcomes.

As explained above, formal governance, partnering, and boundary activities are expected to directly improve IM performance (i.e., H2, H4, and H6). Following the reasoning for H7, it is also likely that IM performance acts as a mediator between these factors and project outcomes. In other words, formal governance, partnering, and boundary activities can all indirectly impact project outcomes through the mediating effects of IM performance (such as facilitating interface tasks).

Empirical Study Methodology

Data Collection

As contractors are responsible to manage information and various resources from other stakeholders for project delivery, they are one of the main entities to implement IM. Therefore, the data collection of this research is mainly based on the perspective of contractors. Specifically, we choose seven Chinese companies ranked as the ENR (Engineering News Record) top 100 contractors in 2019 (ENR 2019). All of these selected contractors have rich experience in delivering large-scale projects (e.g., hydropower projects and railway projects) in the world.

Questionnaire surveys and interviews are employed in this study. The questionnaire survey involved 200 managers whose job responsibilities include inter-organizational coordination or interface management. To ensure a consistent understanding of the concept of IM, the definition of contractor's interface management is provided at the beginning of questionnaire: a process in which the contractor and its interfacing parties jointly create norms, procedures, and structures for managing their common boundaries (i.e., interdependent tasks and working relationships) through communication and coordination, in order to yield mutually satisfactory project outcomes. The questionnaire encompasses two sections. The first one is the informants' personal information (such as positions and working experience) and general information (e.g., project duration, and project type) of one large-scale project that the informants had worked on. The second component of the questionnaire is the items in the conceptual framework (as detailed in the following section). To mitigate social desirability biases of the respondents, additional procedures were used by the researchers (Podsakoff et al. 2003): (1) guaranteeing the confidentiality of all individual response; (2) assuring informants that there are no standard answers to the questions and encourage them to respond honestly based on their experience in reality; and (3) informing informants that the completed questionnaires will be returned to the researcher directly so that the company will not know the detailed information in the questionnaires. After questionnaires, semi-structured interviews with 25 experienced managers were employed to help researchers better understand IM in practice. Each interview lasted about 45 minutes.

Data Analysis Techniques

Statistical analyses were conducted via the statistical package for social sciences (SPSS 24.0). Structural equation modelling (SEM) is performed to analyze the hypothesized relationships in this study. SEM is a statistical procedure for testing predictive and causal hypotheses (Bagozzi and Yi 1988). It has many advantages over traditional regression and correlation analyses, especially in tests of substantive and complex interrelationships. First, SEM significantly simplifies the processes of testing mediation hypotheses as it can offer more integrative and straightforward tests of multiple mediating effects (Bagozzi and Yi 1988). For instance, to test a model consists of one mediating relationship, one should test and compare at least three separate regression models by traditional regression methods; through SEM, however, only one test is needed. Additionally, SEM provides methods to correct systematic bias as it can explicitly calculate systematic error as well as random error (Fornell and Larcker 1981). Analysis of Moment Structures (AMOS 23.0) was employed in both confirmatory factor analysis and SEM analysis.

The sample size of in this research was sufficient to obtain convergent and appropriate results for SEM as recommended by Hair et al. (2009). To further augment the reliability of the analysis results, this research used a bootstrapping sampling method to generate bias-corrected confidence intervals of the mediation relationships and estimate the significance of the mediated paths (MacKinnon et al. 2004).

Measures

Table 1 summarizes the measures of the constructs in the theoretical framework, as shown below.

[Insert Table 1 here]

Table 1. A summary of the measures.

Constructs	Descriptions
1. Formal Governance	
1.1 Plan	A pre-established plan for managing interfaces during the project lifecycle
1.2 Organizational structure	An appropriate organizational structure which is conducive to inter-organizational communication and coordination
1.3 Procedures	Detailed procedures that can be followed for executing IM activities
2. Partnering	
2.1 Trust	The degree of trust between the contractors and: - the owner - the designers - the subcontractors - the consultants - the suppliers - the local government
2.2 Openness	The degree of openness between the contractors and: - the owner - the designers - the subcontractors - the consultants - the suppliers - the local government
2.3 Communication	The efficiency of communication between the contractors and: - the owner - the designers - the subcontractors - the consultants - the suppliers - the local government
3. Boundary Activities	
3.1 Coordinating	Coordinating and negotiating with other key stakeholders in the project about the interface-related issues
3.2 Acquiring resources	Acquiring resources (e.g., information, ideas, equipment) from other companies for completing interfacing tasks

3.3 Informing	Keeping other companies in the project informed of our company's activities
4. Interface Management Performance	
4.1 Effectiveness	The extent to which the project stakeholders meet the specification in IM agreements regarding the quality of the interface task outcome
4.2 Efficiency	The degree of adherence to schedules in the IM process
4.3 Accuracy	The degree of the interface-related information transition being correct or precise
5. Project Outcomes	
5.1 Schedule	The project was completed on time
5.2 Cost	The project was completed without cost overrun
5.3 Quality	The project achieves its goals on quality

Formal governance. Adapted from PMI (2017) and Shokri et al. (2016), we developed three questions to examine the degree of formal governance in the project using a five-point Likert scale (1 represents to strongly disagree, 5 represents strongly agree).

Partnering. Followed prior research (Shen et al. 2017), we adopted a three-item measure to access the level of three elements of partnering in IM, respectively -- trust, openness, and communication. As shown in Table 1, each of these three factors consist of six sub-items, which capture the status between the contractor and the following key stakeholders in the project: 1) Contractors - owners; 2) Contractors - designers; 3) Contractors - subcontractors; 4) Contractors - consultants; 5) Contractors - suppliers; and 6) Contractors - local government. These key stakeholders were selected because they have the most frequent interactions with contractors during project delivery (Tang et al. 2006). All sub-items were assessed by a scale of 1 (very low) to 5 (very high). Then, the responses of the sub-items within each factor were averaged to get factor-level data.

Boundary activities. Build upon on the identification of Ancona and Caldwell (1990) and CII (2014), boundary activities in IM in this study are measured (1 represents to strongly disagree, 5 represents strongly agree) by three types of actions as presented in Table 1.

IM Performance. Following the definition of CII (2014), IM performance is measure by the efficiency of interface task accomplishment, the effectiveness of interface tasks, and the accuracy of inter-organizational information exchange in the projects (1 = very low; 5 = very high).

Results

Descriptive Statistics and Correlation

Out of 200 hard copies of the questionnaires, a total of 168 were sent back to the researchers (response rate of 84%). After eliminating two responses with excessive missing data, there are 166 samples for testing the model. The respondents' average working experience in the construction industry was 11.4 years. 35.1% of respondents are with less than five years, 23.0% are with 5-10 years, 17.6% with 10-15 years, and, 24.3% with more than 15 years. The questionnaires were collected from 85 international large-scale projects, which covered a broad range of project characteristics. As for geographical locations, sample projects are located in Africa (46.00%), Asia (36.00%), South America (9.00%), Europe and Oceanica (9.00%). As for project types, sample projects include power plant projects (67.40%), transportation projects (15.10%), buildings and infrastructure projects (12.80%), and mining projects (4.70%).

Table 2 summarizes descriptive statistics and reliabilities for all constructs. To understand the relationships between constructs, Pearson correlation analysis is also employed, with the results reported in Table 2.

[Insert Table 2 here]

Table 2. Descriptive statistics for constructs.

	Mean	S. D	Cronbach's α	CR	AVE	1	2	3	4	5
1. Formal governance	3.91	0.72	0.83	0.89	0.72	0.85				
2. Partnering	3.67	0.60	0.97	0.97	0.91	0.66^{**}	0.95			
3. Boundary activities	3.86	0.72	0.81	0.88	0.70	0.74^{**}	0.61^{**}	0.84		
4. IM performance	3.81	0.66	0.82	0.82	0.60	0.71^{**}	0.68^{**}	0.74^{**}	0.78	
5.Project outcomes	3.86	0.65	0.75	0.77	0.53	0.62^{**}	0.60^{**}	0.54^{**}	0.60^{**}	0.73

Note: ** means correlation is significant at the 0.01 level (two-tailed); S. D= standard deviations; CR = composite reliability; AVE =average variance extracted; the bold values in diagonal are the square root of the AVEs; non-diagonal values are latent variable correlations. As shown in Table 2, formal governance, partnering, and boundary activities in large-scale projects are significantly correlated with each other, with the correlation coefficients ranging from 0.61 to 0.74 (significance level at 0.01). Among the three factors associated with IM performance, formal governance and boundary activities are highly correlated with IM performance, with the correlation coefficients being 0.68 and 0.74, respectively. These positive estimates of correlation indicate that formal governance and boundary activities have strong positive relationships with IM performance. Also, it is reported that all the variables have positive relationships with project outcomes.

In addition to the descriptive statistics, one-way analysis of variance (ANOVA) were undertaken to evaluate whether there are any significant differences between the means of the constructs in different project categories: (a) project types: power plant, building, transportation, and mining; (b) geographical locations: Asia, South America, Africa, Europe and Oceanica. The results of ANOVA were reported in Table 3.

[Insert Table 3 here]

Table 3. Means of constructs (by project types and geographical locations).

		By project types				ANOVA	By geographical locations				ANOVA
	Total	Power (N=116)	Building (N=12)	Transportation (N=28)	Mining (N=10)	F Statistics	Asia (N=60)	South America (N=15)	Africa (N=76)	Europe and Oceanica (N=15)	F Statistics
Formal governance	3.91	3.92	3.94	3.87	3.87	0.06	3.97	4.04	3.78	4.16	1.68
Partnering	3.67	3.69	3.55	3.62	3.71	0.28	3.80	3.74	3.51	3.90	3.74*
Boundary activities	3.86	3.87	3.97	3.80	3.83	0.16	3.90	3.89	3.74	4.29	2.64
IM performance	3.81	3.83	3.76	3.70	3.92	0.40	3.83	3.79	3.74	4.14	1.59
Project outcomes	3.86	3.93	3.50	3.73	3.77	2.20	3.84	3.98	3.78	4.18	1.82

Note: * significant at the 0.05 level.

In terms of project types, the ANOVA column in Table 3 displays F-test results are all insignificant, suggesting that there is no significant difference between the means of four project types. In terms of geographical locations, results show that there is no significant difference between the means of the four geographical locations apart from partnering. Therefore, the data used in this research can represent a general view of construction projects to a large extent.

To understand the level of partnering between contractors and other project stakeholders, the informants were asked to evaluate the level of trust, openness, and communication on a five-point Likert scale, which are the three basic elements of partnering in IM. The results are provided in Table 4.

[Insert Table 4 here]

Table 4. Level of elements of partnering (i.e., trust, openness, and communication) between contractors and other project stakeholders (1 = low, 5 = high).

	Trust (S.D.)	Rank	Openness (S.D.)	Rank	Communication (S.D.)	Rank
Contractors-Owners	3.88 (0.82)	1	3.69 (0.88)	4	3.59 (0.92)	2
Contractors-Designers	3.61 (0.91)	4	3.75 (0.86)	1	3.51 (0.89)	4
Contractors-Consultants	3.67 (0.83)	3	3.73 (0.84)	3	3.63 (0.87)	1
Contractors-Suppliers	3.70 (0.80)	2	3.74 (0.78)	2	3.58 (0.83)	3
Contractors-Subcontractors	3.46 (0.78)	6	3.59 (0.82)	5	3.40 (0.87)	5
Contractors-Local government	3.59 (0.76)	5	3.59 (0.86)	5	3.39 (0.88)	6

As shown in the second column in Table 3, the level of trust between contractors and owners receives the highest, indicating that both parties attach importance to the establishment of trust relationship and have achieved certain results. As for the openness, the level of openness between the contractors and designers has the highest score (see the fourth column in Table 4), followed by consultants and suppliers, indicating that these stakeholders can share the needed information with contractors without hiding key information. Regarding the communication, the last column in Table 4 shows that the communication efficiency between the contractor and other stakeholders is relatively low (mean value is 3.52), indicating that there are still rooms for improvement. Among the key stakeholders, communication between contractors and consultants scored highest, reflecting frequent and close contacts with contractors, and timely exchange of information. It is noted that the score of communication between contractors and designers is lower than the average level. According to the interviewees reported, language and time difference, as well as the differences between Chinese and international technical standards were the important reasons for low communication efficiency.

Measurement Model Evaluation

Internal Consistency

Cronbach alphas were derived to examine the internal consistency of indicators. Good internal consistency is achieved when the value of Cronbach's alphas is greater than 0.7 (Sharma 1996). With the help of Statistical Package for Social Sciences (SPSS 21.0), Cronbach's alphas of all constructs were calculated (see Table 2). Cronbach's alphas of all constructs range from 0.81 to 0.97, indicating that good internal consistency of the constructs.

Construct Validity

Construct validity is used to reflect the extent to which items of a latent variable measure what they are supposed to measure (Bagozzi and Yi 1988). To test the construct validity, convergent and discriminant validity assessment of latent constructs were performed via confirmatory factor analysis (CFA) using AMOS 23. First, A CFA model was built with 4 latent variables (i.e., Formal governance, partnering, boundary activities, and IM performance) and 14 indicators (see the section of Measures). Satisfactory model fits are achieved when the goodness-of-fit(GOF) statistics meet the following criteria: 1.0$\leqslant$ chi square/degree of freedom (X^2/DF) $\leqslant$3.0, root-mean-square error of approximation index (RMSEA) $\leqslant$ 0.08, goodness-of-fit index (GFI) $\geqslant$0.9, comparative fit index (CFI) $\geqslant$0.9, Tucker-Lewis index (TLI) $\geqslant$0.9 (Bentler 1990). The

GOF statistics imply that the CFA model fits the data well (see Table 5).

[Insert Table 5 here]

Table 5. Goodness-of-Fit measures of CFA and the final model.

GOF	CFA	Final model	Threshold
X^2/DF	2.08	1.64	1.00-3.00
GFI	0.89	0.91	0.9 or above
TLI	0.94	0.97	0.9 or above
CFI	0.96	0.97	0.9 or above
RMSEA	0.08	0.06	0.08 or below

Note: GOF=goodness-of-fit indexes; X^2/DF=chi square/degree of freedom; GFI=goodness-of-fit index; TLI=Tucker-Lewis index; CFI =comparative fit index; and RMSEA=root-mean-square error of approximation.

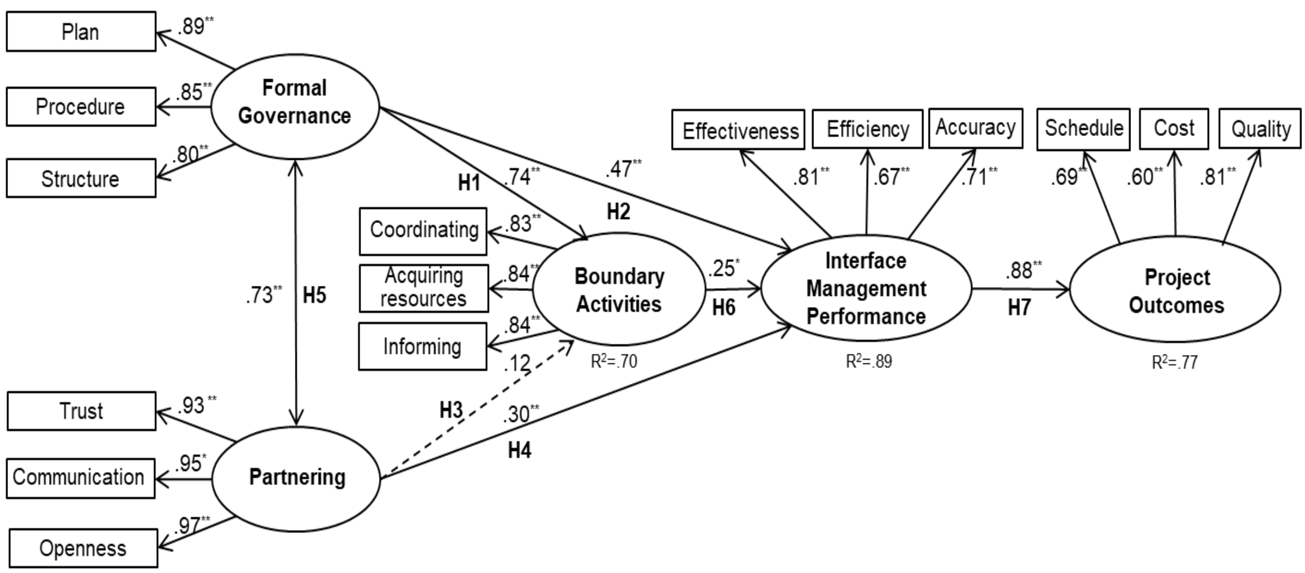
Convergent validity, meaning the degree of homogeneity for a set of items of a latent construct, is assessed by factor loadings, composite reliability (CR), as well as average variance extracted (AVE). Based on the results of CFA, standardized factor loadings of all items range from 0.77 to 0.97 and more than 0.7, which is acceptable (Hair et al. 2009). According to Fornell and Larcker (1981), the value of CR should be greater than 0.70 and the value of AVE should be 0.50 or above to support convergent validity. As reported in Table 2, the composite reliabilities range from 0.76 to 0.98, while the AVEs range from 0.51 to 0.91. The results above indicate that all constructs show good convergent validity.

Discriminant validity represents the extent to which “measures of two constructs are empirically distinct” (Bagozzi and Yi 1988). This type of validity is determined if the square roots of AVEs of every construct are greater than the inter-construct correlations (Fornell and Larcker 1981). As displayed in Table 2, all constructs exhibit good discriminant validity.

Structural Model Evaluation

The SEM was performed to test the framework depicted in Fig.1. After running a bootstrap procedure with 5000 subsamples, the structural model results are displayed in Fig. 2, and the measures of fit are summarized in Table 4 with corresponding thresholds (Bentler 1990). The GOF statistics suggest that the final model fits well.

[Insert Fig 2 here]



Note: **= regression coefficient is significant at the 0.01 level (two-tailed); *= regression coefficient is significant at the 0.05 level (two-tailed); the insignificant path is shown as dashed lines; based on bootstrapping of 5000 subsamples.

Fig. 2. Parameter estimates for the structural model.

Direct Effect. Factor loadings are all statistically significant and error variances low. H1 that Formal governance has a positive impact on boundary activities is supported (β=0.74, $p < 0.01$, R^2=0.70). There is a positive relationship between formal governance and IM performance, as proposed in H2 (β=0.47, $p < 0.01$). Contrary to H3 that partnering has a positive effect on boundary activities, the relationship between these two variables failed to reach statistical significance. H4 and H6 hypnotized that partnering and boundary activities have a positive effect on IM performance, respectively. As predicted, formal governance, and boundary activities emerge as predictors of IM performance, in support of H4 (β=0.30, $p < 0.01$) and H6 (β=0.25, $p < 0.05$), respectively. It was also found that partnering and formal governance are correlated with each other (r=0.73, $p < 0.01$), supporting H5. In support of H7, IM performance is positively associated with project outcomes (β=0.88, p < 0.01). It is estimated that three predictors in the model, namely formal governance, partnering and boundary activities, explain 89% of the variance in IM performance (R^2=0.89).

Mediation Effect. We performed mediation analysis by examining the magnitude and the significance level of two sets of mediation effects in the final model (Wang et al. 2013): 1) the mediation effects of formal governance and partnering on IM performance through boundary activities; 2) the mediation effects of formal governance and partnering on project outcomes through boundary activities and IM performance. The bootstrapping estimates are shown in Table 6, where the magnitude of mediation is calculated as the product of all the standardized path coefficients of the variables in the mediated path (Hoyle and Kenny 1999). The p-values displayed in Table 6 demonstrate that four out of the five examined mediation effects are statistically significant. In other words, boundary activities partially mediate the relationship between formal governance and IM performance. IM performance fully mediates the relationships between formal governance, partnering, and project outcomes.

[Insert Table 6 here]

Table 6. Significance of mediated paths in the final model.

Indirect effects	Mediated paths	Standardized estimates	Standardized errors	Lower bounds	Upper bounds	p
FG→IMP	FG→BA→IMP	0.19	0.09	0.02	0.28	0.02
FG→PO	FG→BA→IMP→PO	0.58	0.08	0.27	0.55	0.00
PA→IMP	PA→BA→IMP	0.03	0.03	-0.01	0.10	0.13
PA→PO	PA→IMP →PO	0.29	0.08	0.11	0.39	0.00
BA →PO	BA →IMP →PO	0.22	0.10	0.02	0.29	0.02

Notes: FG=Formal governance; PA=Partnering; BA=Boundary activities; IMP=IM performance; PO=Project outcomes.

Discussion

Overall, an integrated framework for the effects of formal governance, partnering, and boundary activities on IM performance in large-scale projects has been modeled (see Fig. 1) and empirically tested, with the results summarized in Table 7. The main findings of this paper are discussed below.

[Insert Table 7 here]

Table 7. Summary of the results of the final model.

Hypotheses	Unstandardized estimates	Standardized estimates	p	Results
H1: Formal governance has a positive impact on boundary activities.	0.77	0.74	**	Supported
H2: Formal governance has a positive impact on IM performance.	0.34	0.47	**	Supported
H3: Partnering has a positive effect on boundary activities.	0.16	0.12	0.17	Not Supported
H4: Partnering has a positive effect on IM performance.	0.27	0.30	**	Supported
H5: Formal governance and partnering are positively correlated with each other.	0.30	0.73	**	Supported
H6: Boundary activities have a positive effect on IM performance.	0.18	0.25	*	Supported
H7: IM performance has a positive effect on project outcomes.	0.82	0.88	**	Supported

Notes: **= significant at the 0.01 level (two-tailed); *= significant at the 0.05 level (two-tailed)

First, this study empirically tests formal governance's impact on boundary activities and IM performance. As shown in Table 7, H1 and H2 are supported, which is in line with the statements in prior literature that formalized approaches can contribute to IM practice (Shen et al. 2018a). Fig. 2 illustrates that formal governance can not only exert influence on partnering and boundary activities to improve IM performance but directly facilitate IM performance. That means, the power of formal governance in IM can be reflected in two ways: one way is encouraging formal mechanisms to promote boundary activities and enable effective information processing and coordination; another way is strengthening informal and relational mechanisms (i.e., partnering) for boundary activities. Moreover, formal governance on IM performance is much greater than the impact of partnering and boundary activities, suggesting that it is more effective for fulfilling the goals of IM. As IM has not been widely applied in the construction industry yet, many project participants may lack knowledge and experience about how to implement IM effectively. The temporary project organizations generally undergo a process of adaptation (Savelsbergh et al. 2015). In such uncertain situations, by specifying standardized IM processes and techniques, formal governance can provide project participants guidance on boundary activities and reduce human errors, which can thereby improve the efficiency of collaboration. This can be achieved by establishing pre-established plans, formalized procedures, as well as standardized information and communication systems. The specification in managing interfaces makes the interactions between stakeholders easier because project participants' activities during IM are mainly based on the codified blueprint and thereby more predictable, which will also benefit the development of trust and cohesive environments (Shen et al. 2017). The findings can also help to partly explain why many organizations usually input large amounts of resources to establish a standardized and formal governance system.

Second, in support of H4, this study finds that partnering has a direct impact on IM performance in large-scale projects and its standardized path coefficient to IM performance is the second largest (0.303) among three antecedents. Despite the advantages of formal governance, it is impossible that a contract and procedures can anticipate every possible situation. Partnering has been viewed as an effective strategy to prevent and cope with various unexpected events arising from the dynamic and uncertainty of construction projects (Floricel and Miller 2001). However, there is no evidence to show that partnering has a significant direct impact on boundary activities. Also, according to the findings detailed in Table 6, it seems that boundary activities does not have a mediation effect between partnering and IM Performance. These two results could be attributed to that the “win-win” philosophy of partnering motivates involved parties to openly share the latest information or proactively provide extra important resources, which directly enhances the efficiency and effectiveness of IM, as well as the quality of information exchange (i.e., IM performance). Consequently, in some cases, partnering does not necessarily drive boundary activities such as acquiring and confirming information from other organizations back and forth, which are officially inter-organizational interactions, especially when controlling other determinants such as formal governance. Partnering can indirectly impact IM Performance through improving formal governance.

Third, in support of H5, formal governance and partnering are positively correlated, suggesting that they can mutually reinforce each other. A project stakeholder with sound formal governance such as setting clear plans, appropriate structures, and standardized processes facilitates winning the trust of other stakeholders, and creating open communication among them, which makes the organizational boundaries more flexible and permeable (Crowley and Karim 1995). The enhanced partnering can in turn engage project participants to effectively implement the IM-related plans and procedures. The strong correlation between formal governance and partnering can explain that why the relationship between partnering and boundary activities is not significant after controlling for other predictors’ effects (see Fig. 2), and partnering exerts an indirect impact on boundary activities through enhancing formal governance.

Fourth, the findings show that boundary activities are also a predictor of IM performance. Compared with the other two predictors (i.e., formal governance and partnering), its contribution towards interface management performance is relatively low (0.25), indicating that IM performance is largely driven by formal governance and partnering. In the face of the omnipresent unexpected under varying conditions in large-scale construction projects, formal governance and partnering sometimes are still insufficient to deal with unexpected events because of the inherent organizational boundaries. In such a situation, ongoing interactions (e.g., acquiring resources, coordinating and negotiating) among stakeholders at the boundaries are required. Project participants need to work with both insiders and outsiders of the organization, to obtain information and resources to achieve project goals. Our finding suggests that IM performance largely depends upon the ways people coordinately work together.

Conclusions

Findings

In this study, a theoretical framework has been proposed to examine the interrelationships among formal governance, partnering, boundary activities and their effects on the performance of interface management and project outcomes. With the questionnaire survey and interviews in 85 international large-scale construction projects, the framework has been empirically tested, with the results as below. First, formal governance not only is positively associated with IM performance but also exerts an indirect influence on IM performance through improving partnering and boundary activities. Second, partnering and boundary activities can positively affect IM performance. Third, IM performance has a positive effect on project outcomes. Fourth, formal governance and partnering mutually reinforce each other, and partnering exerts an indirect impact on boundary activities through enhancing formal governance.

Contributions to the Body of Knowledge and Practice

The above results have significant theoretical implications. First, this study contributes to interface management literature by advancing our understanding of how to effectively implement interface management through formal governance and partnering to achieve better project outcomes. While previous research of IM emphasized the merits of formal procedures and systems from a practical perspective (Shokri et al. 2015; Chen et al. 2008; Pavitt and Gibb 2003), this study develops a more comprehensive model to empirically investigate the impacts of formal governance and partnering on IM performance. This empirical research highlights the significance of IM in improving project outcomes. It is evident that enhancing IM can facilitate the effectiveness, efficiency, and accuracy of information flow between organizations, which can help to achieve project outcomes.

Second, although a large body of research has examined the roles of these two factors on project outcomes (e.g., Benítez-Ávila et al. 2018; Ryall and Sampson 2009), it is still not clear how they interactively contribute to improving IM in large-scale projects as IM is an emerging practice in the construction industry. The present study extends the discussion of and empirically tests the relationships between formal governance and relational governance on boundary activities in the context of IM.

Third, different from the complementary and substitutive relationships in most literature (Zheng et al. 2008; Cao and Lumineau 2015), this research provides a more nuanced view on the relationships between formal governance approaches and informal relational approaches: they can mutually reinforce each other. Formal governance can provide assurance for developing partnering and enhanced partnering can in turn engage project participants to enhance the implementation of the plans and procedures, thereby smoothing boundary activities and improving IM performance. Fourth, this research extends boundary theories within the field of construction management. Based on the literature on boundary theories, this research elaborates on the concept of boundary activities in the context of IM, and empirically investigates its mediating roles in improving the final project outcomes.

The outcomes of this study suggest broad managerial implications for project participants in large-scale projects. First, the results of the model (see Fig. 2) highlight the importance of formal governance in promoting IM performance. This implies that institutional standards can foster collaboration and coordination among interface parties. It is suggested that contractors need to make efforts in developing an appropriate project organization structure, and optimizing inter-organizational workflows to facilitate interface tasks. Second, partnering has been proved as a significant factor to promote IM performance in large-scale projects. This indicates that measures should be taken to constantly establishing and enhancing trust, openness, and communication between stakeholders for achieving project goals in terms of schedule, cost, and quality. Third, the survey results reveal the status of partnering between contractors and other key stakeholders, which provide a sound basis to take measures to improve partnering with stakeholders.

Limitations and Future Research Directions

Several limitations have been recognized in this research. First, the theoretical model in this research is tested only by the data collected from the angle of contractors. However, IM in a large-scale project requires all stakeholders' participation. We call for future studies to test and extend the theoretical model by incorporating other views of key stakeholders in construction projects (such as clients, designers, and consultants) to obtain richer insights into this topic. Second, although the sample size is 166, they were collected from seven Chinese contractors of 85 international large-scale projects, which covers a broad range of project characteristics regarding geographical locations and project types. This can reasonably reduce the bias of selecting samples. However, it is suggested that future studies to enlarge the sample size and further investigate IM in different areas and contexts.

Data Availability Statement

All data and models that support the findings of this study are available from the corresponding author upon reasonable request.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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List of Figure Captions

Fig. 1. Conceptual interface management framework.

Fig. 2. Parameter estimates for the structural model.