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The Interactive Effects of Communication Network Structure and Organizational Size on Task Performance in Project-Based Organizations: The Mediating Role of Bootleg Innovation Behavior

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Abstract: A PBO is a temporary organization formed by assembling members with diverse experiences and backgrounds, aimed at achieving specific innovation goals. Constructing a reasonable communication network structure and enhancing organizational synergy are effective ways to promote the sustainable development of the system. This study, based on the Input–Process–Output (IPO) model and social network analysis, utilized a group collaboration platform to conduct a three-stage communication experiment on 685 construction project managers. Under two organizational sizes, the internal mechanism of how communication networks with two levels of centralization influence task performance were tested. The results indicate that in the case of a smaller organizational size, PBOs using a decentralized communication network tend to achieve higher task performance. However, as the organizational size expands, PBOs employing a centralized communication network may surpass in task performance. Additionally, we found that with the expansion of organizational size, bootleg innovation behaviors of organizational members are continually stimulated, further enhancing collective task performance. This study, based on the evolution of communication network parameters, explores the structural characteristics of organizational communication networks and the mechanisms underlying the emergence of bootleg innovation behaviors. It delineates the key pathways for improving collective task performance. The findings can provide a scientific reference for the organizational evolution and development of engineering project management.

Keywords: project-based organizations (PBOs); communication network structure; organizational size; organizational evolution; bootleg innovation behavior; task performance

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1. Introduction

In recent years, project-based organizations (PBOs) have flourished in the construction industry. Their activities typically revolve around projects that encompass infrastructure such as airports, bridges, venues, and exhibitions [1–3]. The development of these constructions has a significant impact on the sustainable development of a city's economy, society, and environment. Research on the topic has branched out into different definitions of PBOs. For instance, some studies consider a PBO as a permanent structure encompassing multiple projects. In contrast, others view a PBO as a temporary legal project-based enterprise or firm created around a specific project outcome [4]. To avoid confusion, this article refers to the latter definition. In such a context, one PBO usually contains diverse participants with different knowledge and professional backgrounds, as well as interactive connections [5,6]. From the standpoint of social network analysis, the members of a PBO and their interrelationships serve as the foundation of its communication network [7]. In fact, the establishment of a PBO was aimed at achieving satisfactory project or task performances [8]. Recent research consistently highlights the significant impact of the communication network structure of a PBO on enhancing construction project performance. For instance, some studies, from the perspective of singular or interactive social network indicators, have explored the influence of the communication network structure on project performance [9,10]. Conversely, other research has analyzed project performance variances within established network structures from the viewpoint of information communication and knowledge-sharing coordination [11,12]. These investigations, through the lens of social network analysis, delve into the effects of organizational communication structures on task performance or project success, providing valuable insights.

The communication networks for PBOs can be categorized by their structural feather—centralization, which is defined as the degree to which communication flows disproportionately through organization members rather than being more equally distributed [13]. Recently, substantial research indicates that decentralized structures, in which organizational members are connected to most or all other members, adapt faster to unique information flows and have increased knowledge-based project performance [14,15]. In contrast, centralized structures, which contain a core leader or a leadership team with groups of peripheries, could improve collective learning and problem-solving ability by providing access to all critical information in a shifting task environment [13]. When further exploring the relationship between these communication networks and task performances, is there significant difference in project performance for PBOs which have adopted different network structures? What type of communication network structure would improve task performance? Further, are there conditions for the desired outcomes? Unfortunately, the answers to these questions remain inconsistent.

Furthermore, the size of an organization, typically measured by the number of employees or total assets, is also considered an important factor affecting task performance [16]. Taking the construction industry as an example, large PBOs often face problems of cost overruns and project delays [17], and there may be a negative correlation between organizational size and task completion [18]. Further, existing research suggests that organizational size and communication network structure are key elements influencing organizational activities [19], which have been presented to be critical factors for task completion outcomes. However, how the interaction mechanism between the communication network structure and organizational size impacts task performance for PBOs remains understudied. Additionally, the relationship between organizational size and technological innovation has always been a matter of debate. The earliest studies believed that the larger the organization size, the stronger its R&D capability and risk resistance, which promotes technological innovation [20]. However, some studies argue that as the size increases, organizational inertia tends to rise, reducing the willingness for technological innovation [21]. Recent studies suggest that the larger the organizational size, the more redundant resources it possesses, which might trigger bootleg innovative behavior among its members. This refers to members of the organization innovating outside of formal channels. In recent years, such bootleg innovative behavior has been considered a motivating factor for improving task performance [22–24].

Thus, effective communication channels facilitate knowledge sharing and knowledge innovation [25,26]. Innovative behavior has been regarded as a key factor in enhancing the vitality of a PBO and in promoting project success [27,28]. However, for construction PBOs with temporary characteristics and engaged in creative production, will the interaction between communication networks of different centralization and different organizational sizes stimulate members' deviant innovative behaviors and further enhance task performance? These discussions have left a series of open questions for traditional research and theoretical perspectives.

Based on the relational contract theory in construction engineering, we identified potential one-to-one correspondences between representative communication network structures and project contract delivery modes. Depending on the position and connections of each node in the network, these three pairs of coupled relationships, from a complete clique structure/Integrated Project Delivery (IPD) mode, a locally clustered structure/Design–Build (DB) mode, to a core periphery structure/Design–Bid–Build (DBB) mode, show a gradual increase in network structure centralization [7,29,30]. At the same time, drawing on the Input–Process–Output (IPO) model [31,32], we examined the impact of communication networks with varying levels of centralization and organizational size on the task performance of PBOs. That is, our study aims to compare the performance differences brought by centralized and decentralized communication networks from the perspective of expanding organizational size, thus filling a research gap. This study also clarifies whether bootleg innovation behavior plays a mediating role in this process.

This study has three theoretical contributions. Firstly, building on recent studies that explore project performance improvement from the perspective of network structure metrics for PBOs, this study examines the interactive relationship between communication network structure and organizational size based on collective tasks, including individual task execution, internal information sharing, and collective decision making. This enriches the research results related to improving project performance. Secondly, this study explores the intrinsic mechanism of performance improvement in PBOs by bootleg innovation behavior, expanding the research of innovation management in the construction industry. Thirdly, the conclusion of this study explores the relationship between organizational size and bootleg innovation behavior from the perspective of organizational evolution in project organizations, expanding the scope of issues addressed in project management.

The next section of this paper presents a literature review and hypothesis formulation. Section 3 introduces the experimental design, procedure, and measurements. Section 4 presents data analysis and test results. Section 5 discusses the results, outlining theoretical contributions and managerial implications. Lastly, Section 6 is the conclusion, including discussions on limitations and suggestions for future research.

2. Literature Review and Hypotheses Development

2.1. Theoretical Foundation: Input–Process–Output Framework

McGrath proposed an IPO framework for analyzing collective behavior and performance [31]. The IPO model clarifies the impact of inputs on outcomes through the interaction process. Inputs are described as antecedents that enable and constrain organization interactions, which include individual-level factors (e.g., competencies and personalities), team-level factors (e.g., structure and size), and environmental-level factors (e.g., task features and environmental complexity). These antecedents from different levels combine to drive team interaction processes toward task accomplishment. Processes are used to describe the emergent states of how inputs are transformed into outcomes. There are multiple criteria for outcomes. They may include task performance (e.g., quality, speed to solution) and members' affective reactions (e.g., member satisfaction, cohesiveness, viability). The IPO model has served as a foundation for research on collective performance outcomes, and it has also been involved from perspective of composite performance measures [32].

2.2. Communication Network Structure and Centralization

The construction of engineering projects is fraught with uncertainties [33–35]. By establishing a PBO, members with diverse skills, experiences, and tools can be brought together [36–38]. Individuals offer support to others through innovative activities, ultimately achieving task objectives within specified time, cost, and quality constraints [28,39]. Throughout this process, organizational members need to make efforts to share private information with others, and the knowledge acquired and internalized by other members can be externalized as knowledge collectively held, shared, and agreed upon within the organization [40]. Processes of collective knowledge acquisition, sharing, integration, and updates will heavily rely on the communication structures. Therefore, how to measure a communication network structure has attracted more widespread attention. Recently, social network analysis has been described as a tool for analyzing the complex interrelations through network structures, whereas network attributes related to roles, interactions, linkages, and metrics are discussed [41].

Based on existing research, a key feature of a communication network structure is centralization [42,43]. For a PBO, as the inequality or disparity in the number of contacts a group member has with others increases, the degree of centralization also increases [44]. Therefore, from the perspective of centralization, communication network structures can be categorized into two types: centralized structures and decentralized structures. For instance, the core periphery structure is a commonly observed centralized structure in empirical studies. It consists of an internally fully connected core subnetwork and peripheral individuals connected to the core but not each other. Those situated within the core subnetwork wield substantial control over the network's overall functions. In contrast, the peripheral participants play a pivotal role in shaping project objectives by channeling essential resources to the core [30,45]. This type of communication structure is often associated with the DBB contract delivery model. Core enterprises (such as the owners) interface with peripheral enterprises (such as the designers, constructors, and supervisors). There are no contractual relationships between the peripheral enterprises, nor is there an official flow of information.

However, an increasing number of studies indicate that centralization may also have its flaws because a person or persons in the periphery cannot share ideas or information directly with each other, or the key information that must flow through cores may be a bottleneck for collective problem solving [46,47]. Moreover, the central nodes may lead the whole organization by their bias, should they adopt bad ideas or bad solutions [48]. In contrast, decentralized structures have largely attracted more favor in which members can directly communicate with each other rather than just with a core. the structure of a complete clique includes a group of members, all of whom are connected to each other, like a large workgroup or organization members using a single shared digital communication channel. For instance, a complete clique structure wherein individuals can freely interact with others. Organization members are able to learn each other's skills and expertise more fluently and coordinate the interdependent activities between members, where each member contributes to maximize the collective benefits [29,41]. This structure is often found in the PBOs of the IPD delivery model, where each member shares responsibility and risk. Maximization of project performance is achieved based on the insights and talents of each organizational member [49,50]. In addition, the locally clustered structure consists of interconnected subgroups. Each subgroup attends to a specific aspect of the project. Interactions, such as knowledge and resource transfer, are concentrated within the boundaries of subgroups and are relatively sparse between them [13,30]. For mega-projects, when the EPC general contractor cannot handle all the tasks, multiple DB subunits are established. Each DB is interconnected through schedule and cost interfaces. Contractual relationships also exist within the subgroups. Decentralized structures are presented to adapt to shifting environments with faster information flows and increased knowledge-based work [13].

To further improve performance from a communication network structure perspective, researchers move a step closer to resolving the questions above by integrating centralization with other structure metrics (e.g., network density) or external environmental factors (e.g., adaptability to shifting environment) which unite these disparate findings under an integrated theoretical roof. However, to the best of our knowledge, related research in the construction industry still needs to be expanded to explore the characteristics and trial conditions of varying communication networks from a more wide structural metrics perspective.

2.3. Organizational Size and Network Size

A PBO is constructed to create innovative products or services [5,51]. Organizational size for a PBO can be measured by various aspects, including number of employees, turnover, and total balance sheet [52]. It has been identified that organizational size will affect the management mechanisms adopted by the organization and the interests of members [53], the organizational financial capacity, and innovative performance [54]. It is worth noting that, on the one hand, a larger organizational size improves the ability of the organization to cope with complex and uncertain tasks [55]. On the other hand, a larger organizational size is accompanied by a more complex organizational structure [56], which, in turn, increases the difficulty of management and increases the uncertainty of task completion [57].

From a network structure perspective, we obtained similar findings. The network size has a significant impact on the effectiveness of network governance. A small size is beneficial in trust-building among participants because it is easier for a small group of members to interact and communicate directly than for a large number of participants. And a network with small size can help to allocate physical and human resources to projects in a timely and accurate manner, as well as increase responsiveness and allow for the discovery and utilization of dispersed knowledge [58]. Specifically for knowledge workers, a larger communication network is not better due to time and energy constraints [59]. However, if there are too many tasks, a large-scale network with abundant resources is indispensable [58]. Based on the discussions above, we suggest that the key impact of organizational size should be further explored to improve task performances of PBOs.

2.4. Communication Network Structure, Organizational Size, and Task Performance

In recent years, people have been discussing the differences in task performance brought about by adopting centralized communication networks versus decentralized communication networks. Many studies suggest that decentralized structures have more communication channels which facilitate adapting faster to information flow and innovative work based on increased knowledge [14,15]. However, some new research suggests that centralized structures have advantages in uncertain and complex external environments. For instance, when there is staff turnover, new members might find it challenging to quickly understand and participate in communication within a decentralized structure, which may harm the task performance. In contrast, within a centralized structure, new members can quickly discern the set communication channels and established coordination procedures, proactively offer fresh insights and data to central nodes, and aid in completing tasks [44]. Recent experiment-based research aligns with this finding, indicating that within a centralized structure, the core node exclusively upholds the somewhat autonomous peripheral nodes, without imposing uniformity demands on its members. Such a setup fosters the creation and linkage of varied approaches, facilitating the dissemination and adaptation of potent concepts in an ever-evolving context [13]. For PBOs in the construction industry, the limitation of the construction period has always been a key issue in project management, and the ability to handle tasks quickly is undoubtedly beneficial. On the other hand, from the perspective of organizational size, when the organization is smaller in size, decentralized structures achieve better task performance due to their numerous communication channels [7]. However, as the organization grows larger, centralized structures can enhance task performance by increasing the average communication frequency on available paths [44]. Different types of construction projects have varying scales, and they also face numerous uncertainties.

These streams of research for the IPO model and the previous discussions lead us to question: Does the interaction between the communication network structure and organizational size affect task performance in PBOs? Under which communication network structure, and at what level of organizational size, will a higher task performance be inspired? To answer these questions, we first need to clarify whether the interaction between the communication network structure and organizational size will have an impact on the project performance for PBOs. Following this, we present the differences in task performance between centralized and decentralized structures across two organizational sides. We posit that

H1. *Communication network structure and organizational size interact to affect task performance for PBOs in construction industry.*

H1a. *When the organizational size is smaller, communication networks with decentralized structures can lead to superior task performance.*

H1b. *When the organizational size is larger, communication networks with centralized structures can lead to superior task performance.*

2.5. The Mediator of Bootleg Innovation Behavior

In an organizational environment characterized by diversity, boundarylessness, and openness, innovation is incrementally considered to be a critical way to improve performance for most types of organizations [60]. The activities, structures, and rules to achieve innovation will affect an organization's innovation speed and outcome [61]. To break deliberate strategies which may hinder organization innovation [62,63], bootleg innovation is presented as a portfolio approach, improving organizations' innovation tendency and ability [22]. Bootleg innovation is defined as bottom-up or unplanned ideation activities through which innovation ideas are initiated and elaborated without authorization but to the benefit of the organization [64]. The previous research mostly focused on bootleg innovation behavior and innovation performance from an individual perspective. For instance, the relationship between innovation climate, costs, and benefits and the willingness and behavior of organization members [24,65]. It is noteworthy that the success of bootleg innovation lies in the organization situation, not the bootlegging behavior itself [66]. Hence, a few studies have tried to explore the role of bootleg innovation from a collective perspective. For instance, the bootleg innovation tendency at an organizational level can be intentionally regulated and implemented, contributing to organizational renewal and innovation [67]. However, if an organization has constructed an appropriate innovation management structure, excessive bootlegging may dismantle its efficiency and effectiveness [68].

As an organization that aims to innovate products or services, an effective organizational structure can reduce management complexity by facilitating communication and innovation [69]. PBOs in the construction industry are usually operated within an established network structure and communication channels and facilitate the innovation process through knowledge sharing. On the one hand, organization innovation will improve task performance as well as project success [70]; on the other hand, the innovation process will take time, which is in contradiction with the time limitations for task completion of a construction project [71]. Could bootleg innovation be a strategy to resolve this paradox? Based on our literature review, research on bootleg innovation in PBOs still requires further exploration. Furthermore, as the structure of the communication network and organizational size are key parameters reflecting organizational characteristics, they will also influence the collective inclination towards innovation [72]. Therefore, examining PBOs that adopt various communication network structures and identifying at which organizational sizes they are most likely to initiate bootleg innovation, and subsequently assisting organizations to break through challenges in enhancing project performance, is of paramount significance. These arguments lead us to expect that

H2. *Bootleg innovation behavior mediates the impact of the communication network structure (centralized vs. decentralized) on task performance for PBOs in the construction industry when the organizational size is larger.*

Therefore, based on these three hypotheses, this study proposes the theoretical model shown in Figure 1.

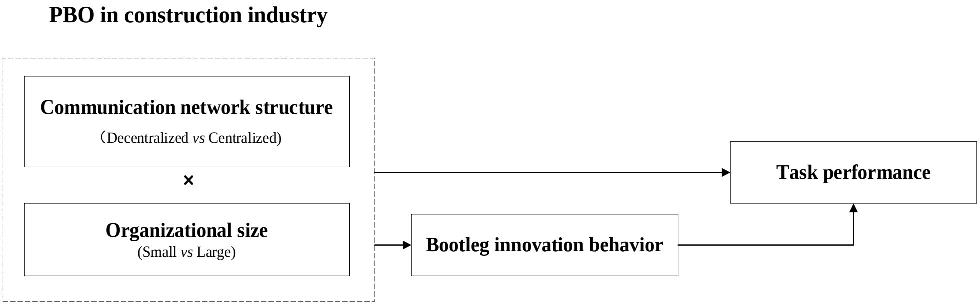


Figure 1. Theoretical model.

3. Methods

3.1. Research Overview

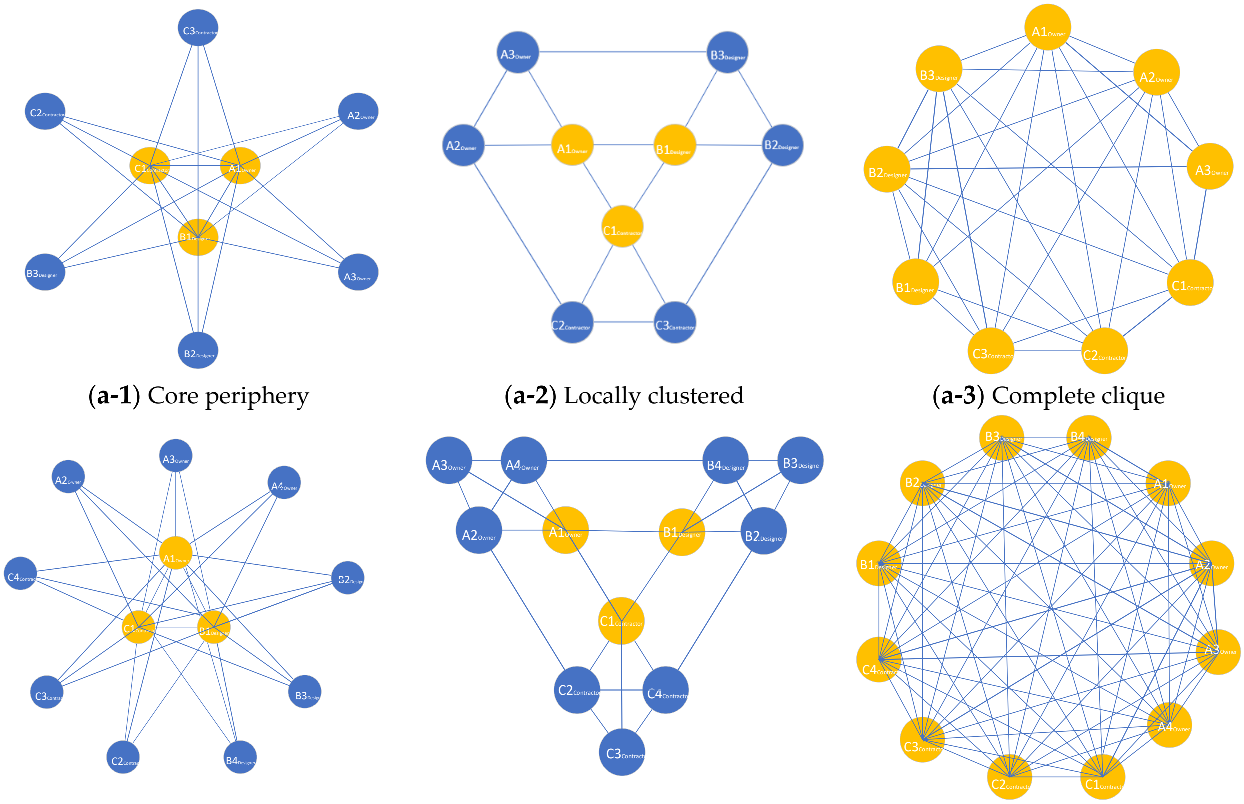
The aim of this study is to explore the impact of communication network structures and organizational size on task performance for PBOs in construction industry (H1). Furthermore, by studying the behavior of organizational members, we seek to determine which organizational sizes best support performance improvements within communication networks of varying centralizations. In addition, we attempt to demonstrate the conditions for the mediating effect in bootleg innovation behavior (H2).

As each PBO is unique, such as in their organizational size, mission characteristics, and environmental factors [73,74], it is difficult to accurately extract the impact of specific communication network features on project completion by directly observing and collecting data via scenario surveys. Current research has utilized gaming experiments to collect data, simulating the actual challenges faced in the work environment [44,75]. Participants are able to immerse themselves in these particular situations and give authentic feedback to accomplish the given tasks, allowing researchers to examine their actions and outcomes [76,77].

Based on the Bavelas–Leavitt–Guetzkow series of experiments [78–80] and the latest communication network experimental framework [13,44], this study designed an online communication and collaboration experiment platform to simulate the activities of PBOs in the construction industry. By observing and recording the individual work and collaborative performance of participants under specific communication conditions and task requirements, we aim to validate our hypotheses. The main features of this experimental scenario are as follows: First, the realism in the replication of the scenario, where the communication network structure is derived from existing case studies. Second, the accessibility of task execution, where the collective task execution process is similar to real-life scenarios, and task requirements are easily understood and executed by participants with construction project experience. Third, the feasibility of variable measurements, where participant performance, task completion status, and other variable measurement data can be monitored and recorded through the system platform.

3.2. Experiment Treatment

The basic setup of the experiment originates from the fundamental characteristics of PBOs, which are that various professionals achieve task objectives through communication and collaboration. Before the main experiment, we conducted a pilot study to verify the experimental design and ensure appropriate measurement of the relevant variables. In the experiment, we manipulated two variables: communication network structure and organizational size. First, the communication network structure is described through network centralization. We set up three communication structures: (1) complete clique, where all members can communicate with each other; (2) locally clustered, where subcliques can communicate internally with certain members connecting externally; (3) core periphery, where core members are interlinked and peripheral members connect with only one core member. We built the communication network using communication clients and recommended communication partners to participants based on network features. Second, based on the basic setup in a PBO where all members are part of the communication network, the organizational size is reflected by the number of members in the communication network. Based on existing research [13], this experiment establishes communication networks of two organizational sizes, with node counts of 9 and 12, respectively. Each node corresponds to a member, who play the roles of owner, designer, and contractor. They possess information specific to their professional fields. Yellow node members have more decision-making authority than blue node members. Communication network structures are formed through pairwise communication and collaboration among members. Therefore, communicating and collaborating with non-recommended members is considered as bootleg innovation behavior. Essentially, this study employed a 3 (communication network structure: complete clique, locally clustered, core periphery) × 2 (organizational size: small, large) between-subject design (Figure 2).



(**a-1**) Core periphery (**a-2**) Locally clustered (**a-3**) Complete clique

(**b-1**) Core-Periphery (**b-2**) Locally clustered (**b-3**) Complete clique

Figure 2. Network visualizations. (**a-1**–**a-3**) Network within smaller organizational size (9 points); (**b-1**–**b-3**) Network within larger organizational size (12 points).

Participants, after being randomly assigned roles, will obtain an exclusive information library containing ten pieces of private information. This means they have different communication and information access rights. Only roles represented by the orange dots have the authority to integrate information. Connection relationships indicate that they are recommended communication collaboration partners. Each step in the process includes specific task requirements and key hints. Under the guidance of these hints, participants search for crucial information in their respective information libraries and share it with recommended or non-recommended partners. Members with integration capabilities combine three different pieces of information to complete each process step. Notably, multiple process steps can be executed simultaneously. Within 30 min, the groups formed by the participants need to analyze tasks, extract vital data, pair up to share information, and combine the three key pieces of information to ultimately complete a program. These participants need to complete a total of 40 programs in a specific order. An example of the experimental interface can be seen in Figure 3.

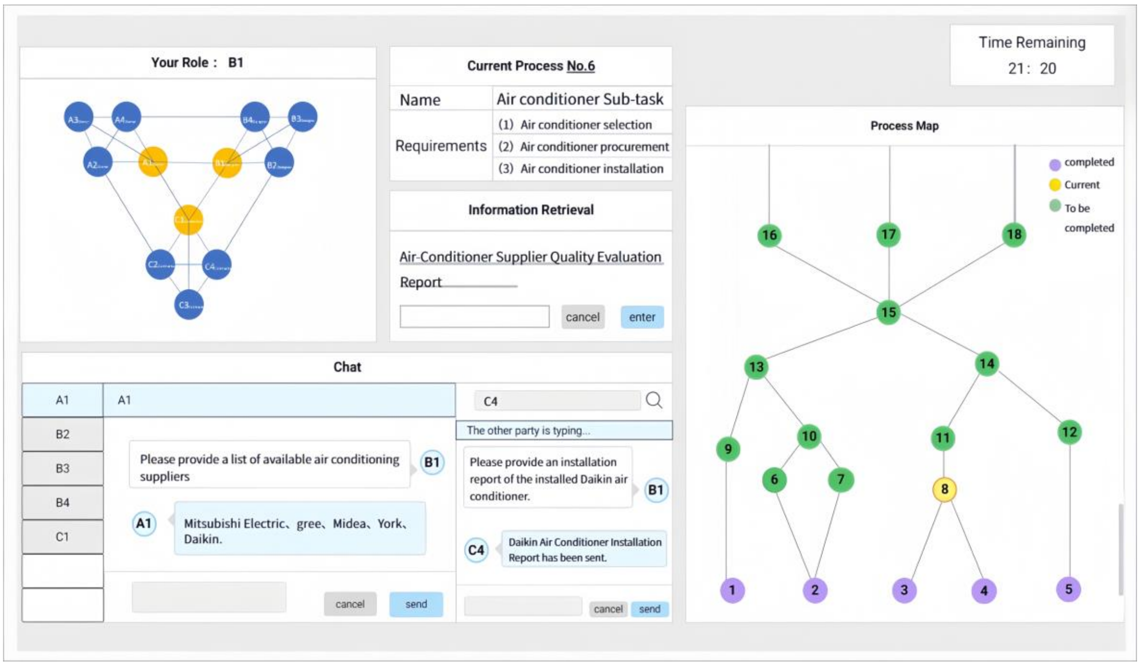


Figure 3. Screenshot of the experimental interface.

3.3. Measures

Both the mediating variables and the outcome variables in this study were measured through behavioral measures. Following a suggestion from [81], we took the number of operations completed by the group within 30 min as the task performance. Referring to the manipulative materials on pro-social rule violations [82] and based on the definition of bootleg innovation, this article takes the communication collaboration behavior between non-recommended communication partners as a measure of bootleg innovation behavior. In this context, when one member sends a message to another member, it is counted as one instance of bootleg innovation behavior.

3.4. Sample and Procedure

Utilizing expert interviews and targeted recommendations, a total of 685 participants were enlisted from Shanghai and Changsha, China. These individuals are either currently engaged in or have previous experience in engineering project management. Participants who complete the formal experiment will receive a ¥50 shopping card. Additionally, the best-performing group in each scenario will receive an extra ¥100 shopping card per person. Following the recommendations of Meade and Craig [83], as well as Shore, Bernstein, and Jang [13], a three-phase participant pipeline is established, as shown in Figure 4.

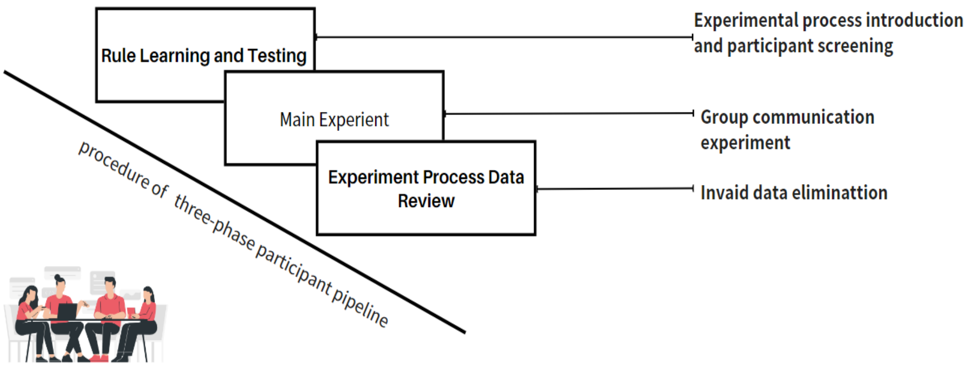


Figure 4. Experimental procedure.

First Phase: Rule Learning and Testing. Upon entering the lab, each participant sat in front of a computer in a private booth, watching a video explaining communication rules and the operating interface. After the video, participants answered seven questions about experimental rules based on a given scenario (See Appendix A). Participants who failed the test could attempt up to 3 more times.

Second Phase: Main Experiment. Participants who passed the first phase of testing entered the main experiment. They were randomly assigned to groups of 9 or 12 people and given specific roles. Under the recommended communication partners and specified role permissions, they collaborated to complete a task within 30 min through information extraction, information sharing, collective decision-making. Finally, participants filled out a survey about their basic personal information, such as gender, age, and work experience, which may influence their cognition and behavior in communication and collaboration, to serve as control variables [76,84].

Third Phase: Experiment Process Data Review. We checked each participant's message sending frequency to determine which participants sent messages significantly fewer times than the team average or sent repeated or invalid messages more than three times. Those with insufficient participation were excluded from their respective group's data. The implementation of the first phases and third phase aimed to identify and eliminate participants who did not follow instructions, lacked concentration, or were unable to complete tasks correctly. To minimize potential confounding factors, like uneven practice or fatigue effects, each participant could only join the main experiment once [85].

As this experiment was conducted in groups, we had to tolerate situations where the experiment could not commence due to an insufficient number of participants in each group. We provided opportunities for those participants who were not grouped the first time but were willing to continue to wait and join the next experimental group. To achieve a balanced sample, we repeated the procedure of the aforementioned three stages until we could no longer recruit more participants to maintain group balance, at which point data collection was halted. Ultimately, seven individuals could not partake in the main experiment due to either not passing the first-stage test or failing to be teamed up. Additionally, we excluded invalid data from three groups filtered out in the third stage and data from two groups that exceeded the sample balance. In the end, we recorded data from 10 groups in each scenario, totaling 60 groups of data. Based on the valid data from 630 participants, the average age was 32, with 57.3% male and 42.7% female participants. Furthermore, 36.2% had one to three years experience; 40.6% had three to five years experience; and 23.2% had more than five years experience.

4. Results

4.1. Manipulation Check

Referring to the research of Argote, Aven, and Kush [44], through the analysis of experimental process data, we conducted a manipulation check on the communication network structure. By examining the communication targets of group members, we observed the following: First, the communication frequency with recommended communication partners was significantly higher than with non-recommended ones ($p < 0.1$). Second, under the core periphery structure, the usage rate of available communication paths by the core nodes was slightly higher than that of other members ($p < 0.1$). In contrast, under the locally clustered structure and complete clique structure, there was no significant difference in the usage rates among members ($p > 0.1$). This suggests that the manipulation over the communication network structure from the centralization perspective is effective.

4.2. Testing of the Main Effect

First, a two-way ANOVA was carried out using the communication network structure and organizational size, taking task performance as predictors. The results indicated a significant interaction between the communication network and organizational size (F (1.54) = 25.498, p = 0.000, $\eta^2{}_p$ = 0.486). Following this, a one-way ANOVA was used for simple effect analysis. As shown in Figure 5, when the organization size was smaller, the task performance of the locally clustered structure (M = 34.10, SD = 2.644) was significantly higher than the core periphery structure (M = 25.60, SD = 2.633; F (1.18) = 20.909, p = 0.000, $\eta^2{}_p$ = 0.742). Additionally, the task performance of the complete clique structure (M = 31.40, SD = 3.026) was significantly higher than the core periphery structure (M = 25.60, SD = 2.633; F (1.18) =20.909, p = 0.000, $\eta^2{}_p$ = 0.573). Thus, H1a was supported. On the other hand, when the organization size was larger, the task performance of the core periphery structure (M = 24.70, SD = 3.889) was significantly higher than the locally clustered structure (M = 20.70, SD = 1.947; F (1.18) = 8.461, p = 0.000, $\eta^2{}_p$ = 0.320) and the complete clique structure (M = 21.40, SD = 2.675; F (1.18) = 4.888, p = 0.004, $\eta^2{}_p$ = 0.214). Thus, H1b was supported. Therefore, H1 was validated.

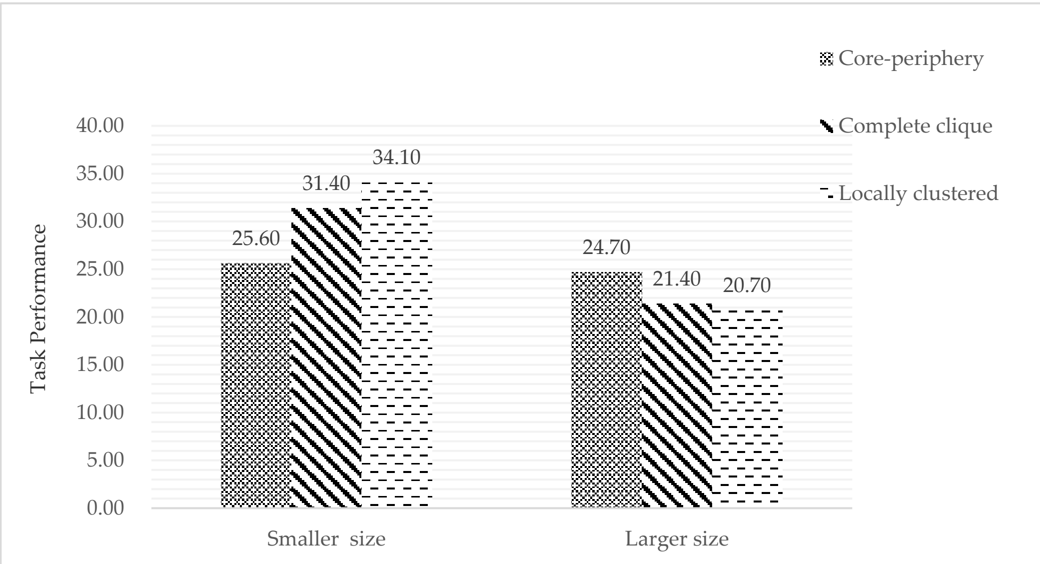


Figure 5. Task performance of interaction between communication networks and organizational size.

4.3. Testing of the Mediation Effect

The PROCESS was used to test the mediation effect. Model 4 was chosen with a sample size of 5000 and a 95% confidence interval, according to Hayes [86]. Due to the characteristic of the complete clique structure with fully interconnected members, bootleg innovation behavior does not exist and is not included as a research object. The results showed that, under a smaller organizational size, Effect (core periphery vs. locally clustered) = −0.416, 95%CI = [−0.3076, 0.0924]. The interval includes 0, indicating that the mediation effect of bootleg innovation behavior is not significant at this time. However, under a larger organizational size, Effect (core periphery vs. locally clustered) = −1.4170, 95%CI

= [−2.9063, −0.3162]. The interval does not include 0, indicating a significant mediation effect of bootleg innovation behavior at this time. Hypothesis H2 is supported.

5. Discussion

5.1. Main Findings

Although there has been an increasing number of studies using social network analysis metrics to explore the relationship between organizational collaboration and project performance for PBOs in the construction industry, research examining the role of communication network characteristics on member's bootleg innovative behavior and their impact on task performance is still scarce. Our study, which involved communication experiments based on individual tasks, information sharing, and collective decision making, with 685 construction project management professionals, yielded the following findings:

For a PBO, the impact of the communication network structure on task performance is moderated by organizational size. Specifically, when the organization is smaller in size, a decentralized structure can achieve better task performance than a centralized one. Conversely, in larger organizations, the task performance of centralized structures surpasses that of decentralized structures. This means that the influence of organizational size leads to opposite outcomes in the effects of communication network structures. Multiple factors might explain this phenomenon. In a decentralized structure, there are more central node members spread out, resulting in dispersed power. When the organization is smaller, it benefits members with various experiences and capabilities to fully utilize their potential. While completing individual innovative tasks, they use numerous communication channels to share information externally, prompting a vast amount of effective collaboration within the PBO, swiftly enhancing task performance. For instance, the decentralized structure represented by the IPD contract model promotes strategic alliances among all members throughout a project's life cycle. This can achieve efficient and rapid collaborative work, especially for highly innovative tasks. This strategy meets all organizational member interests and requirements, aiding in achieving strategic objectives [87,88]. The strength of a decentralized structure is that it encourages more members to share knowledge and contribute insights to collective decision making. However, as the organizational size grows, quickly concentrating manpower and material resources often becomes challenging, exposing the issue of incomplete information or resources under a single dispersed channel [89,90]. At this point, the central node in the centralized structure can leverage its positional advantage, helping to form Simmelian ties of extremely high strength and stickiness [91]. That is, coordinating production resources, mobilizing appropriate organizational member activities, focusing on key issues, and improving the production efficiency for a PBO. A case from the 2010 Shanghai World Expo shows that, under urgent tasks and difficult coordination, establishing a project command composed of experienced senior executives from relevant government departments can integrate various resources. With efficient communication and coordination, the project progress can be accelerated, improving completion quality [92]. Research on the mega-project of the 2012 London Olympics also supports this conclusion, suggesting that project managers play a crucial role in strengthening organizational coordination and integrating management teams [93,94].

Furthermore, this study explored the evolutionary mediating effect of bootleg innovative behavior between communication network structure and task performance across different organizational sizes. Specifically, in smaller PBOs, the mediating effect of bootleg innovative behavior between communication network structure and task performance is not significant. However, as the organization grows, bootleg innovative behavior has been validated as the intrinsic mechanism through which communication network structure affects task performance. In smaller organizations, members have relatively smooth channels to collaborate with others, establishing collective decisions based on knowledge sharing and rapidly enhancing task performance [84,95]. As organizational size increases, communication between members and core members becomes increasingly challenging. Especially within limited task timeframes, when innovation plans based on formal communication channels encounter obstacles, members might opt for bootleg innovative actions to generate more profits for the organization and demonstrate their value. The goal is to ensure the organization achieves its innovation targets, subsequently benefiting the project [23,24]. This situation mirrors the triggering scenarios of bootleg innovative behavior in traditional organizations, emphasizing members' autonomy, concealment, and informality in innovative activities [96].

5.2. Theoretical Contributions

This article describes the impact of the interplay between communication network structure and organizational size on task performance for PBOs in the construction industry. This allows us to contribute to the current literature on project management, mainly reflected in the following aspects.

Firstly, based on recent studies that explore the collaborative relationships of project organization members from a social network analysis perspective [41,97], this research advances our understanding of the relationships in organizational structures for PBOs by revealing the fundamental role of communication network structures and how communication networks with different centralizations affect task performance moderated by organizational size. Especially for large-scale PBOs, which are easily affected by unstable, complex, uncertain, and ambiguous environments over the lengthy project construction cycle, a centralized structure can play a significant organizational synergy role from the individual to the collective level, thus improving project performance [2,98].

Secondly, this study expands the literature on the application of innovative behavior in construction project management. The experimental results of this study confirm the driving force of bootleg innovation behavior on task performance under certain communication network structures. The occurrence of this behavior is closely related to the duration requirements of construction projects, reflecting the behavior of organizational members creating more profits for the organization and the desire to realize their self-worth [99,100].

Thirdly, since organizations are embedded in social systems, their strategic actions are largely influenced by the social environment. Due to the contextual and strategic nature of construction projects, their size has always been a focal point [23,101]. This study expands the element of organizational size from the conventional perspective of a control variable to an independent variable, exploring the evolutionary development relationship between organizational size and innovation behavior, thereby enriching the research boundaries of management in PBOs.

5.3. Managerial and Practical Implications

This study offers significant insights for decision makers and leaders in construction project management. Within PBOs in the construction industry, there is a need for an adaptive communication organizational structure based on the behavior and interaction coordination of organization members, which is crucial for organizational performance management.

It is worth noting that communication and coordination between organizational members play a vital role in enhancing project outcomes. When executing projects, decision makers should gather workers with diverse knowledge and backgrounds based on the project type and environmental factors and establish an appropriately centralized communication structure. On the one hand, using the 2020 Dubai Expo as an example, appointing a central coordinator as the hub is essential for large-scale PBOs. It is recommended to implement coordination among sub-projects by building management teams and coordinating resources. This approach aims to mitigate potential negative impacts brought about by daily changes and disturbances, thus improving collective outcomes [94]. The solution is approached from a central collaborative perspective. On the other hand, in the context of medium and small organizations, members with different professional expertise in a decentralized communication structure have clearer rights and responsibilities. This promotes knowledge exchange and sharing, forming efficient task decisions based on lean construction concepts. This type of organizational structure also provides adaptive collaboration for the work coordination problems that often arise during project progress [102,103].

However, leaders should also recognize that, under certain relational structures, even if formal task interdependence channels are formed between members, interactions among them may not effectively occur due to various challenges. Therefore, managers should pay attention to employees' deviant innovation behaviors and focus on individual employee autonomy in innovation and creative performances. Our research suggests that, especially in larger-size PBOs with tight project timelines, deviant innovative behaviors have a positive effect on enhancing project performance. Leaders should foster innovation among employees by strengthening their psychological capital and work enthusiasm, thereby enhancing their innovative capabilities [104–106].

6. Conclusions

This study, grounded in the IPO model and combined with relational contract management practices, explores the relationship between the communication network structure, organizational size, and task performance of PBOs in the construction industry. We did this by focusing on key indicators of communication networks—centralization and size—using a communication experimental platform. We summarized organizational structure features across different task scenarios, identifying key factors to elucidate internal organizational relational mechanisms. The number of people in the organization, the roles they play, structural hierarchies, experimental scenarios, as well as methods to measure task and goal variables, are representative both in theory and practice. Our experimental findings revealed that smaller-sized organizations achieved improved task performance when PBOs utilized a decentralized communication network. As the organizational size expanded, centralized communication-network PBOs demonstrated superior task outcomes. Furthermore, we observed that when the organizational size increases, it could stimulate deviant innovation behaviors among employees, subsequently aiding in enhancing task performance.

However, due to the diversity of types of PBOs in the construction industry, this study cannot precisely present and measure all the structures in reality. For instance, some mega-projects are more suited to a combination of multiple organizational structures. Additionally, due to the limitations of experimental conditions, the design of organizational size is referenced from classical experiments and limited to two levels. In the future, trend characteristics can be obtained by increasing measurement levels. The measurement of bootleg innovation behavior can also be expanded in multiple dimensions, including the structure to which it belongs and the manner of behavior. In the future, field experiments can be combined with laboratory experiments. Based on the findings of this study, case studies corresponding to specific scenarios can be added to validate or expand the conclusions of this research. Furthermore, our study, conducted exclusively in China, did not account for the influence of cultural variations on organizational member behavior. Future research could benefit from incorporating diverse backgrounds and participant viewpoints to broaden the scope of understanding.

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Appendix A

Table A1. Questionnaire in first phase of participant filter.

Item	Measure
1	How many people are in your team?
2	What is the total duration of your tasks?
3	Who are the recommended communication targets for you?
4	What is the ultimate goal of your team?
5	What are the requirements for completing each process?
6	Do you have the authority to assemble information to complete the process?
7	How many tasks did you finally complete?

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