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THE ROLES OF PARTNERING AND BOUNDARY ACTIVITIES ON PROJECT RESILIENCE UNDER DISRUPTIONS

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Abstract. Construction projects inevitably encounter adversities that threaten their functionality and performance. Understanding the enhancement of project resilience, especially in extreme situations like the COVID-19 pandemic, is crucial. This study introduces a theoretical model to explore how partnering and boundary activities among project stakeholders influence project resilience, and in turn, impact project performance. Based on data gathered from a questionnaire survey involving 172 construction projects in China, the results indicate that project resilience directly and positively affects project performance during the COVID-19 pandemic. Partnering and boundary activities emerge as primary determinants of project resilience. They not only directly impact project resilience and performance, but their impact on project resilience also indirectly influences project performance. The findings offer valuable theoretical and practical insights into the improvement of project resilience through effective boundary activities and partnering.

Keywords: resilience, boundary activity, partnering, crisis management.

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1. Introduction

Construction projects with a wide range of complexity and uncertainty are inevitably vulnerable to extreme and changing conditions (Naderpajouh et al., 2020). For example, the COVID-19 pandemic has caused unforeseen interruptions in construction projects worldwide, which have shown various levels of performance and resilience. Some projects have been suspended due to labor and material shortages or interruption in the capital chain; conversely, others have shown efficient response to disruptions, rapid production resumption, and on-time project delivery (Wang et al., 2021). These various outcomes indicate that projects' resilience over disruption is a phenomenon of considerable theoretical and practical importance. Growing economic, natural, and social uncertainties that threaten the resilience of construction projects have drawn increasing attention from the construction industry (Lim et al., 2021).

Project resilience refers to "the capacity of the project system to be aware of its surroundings and vulnerabilities, and to adapt in order to recover from disruptive events and achieve its objectives" (Rahi, 2019). Most previous studies on project resilience focuses on its connotation (Naderpajouh et al., 2020; Kutsch et al., 2015; Rahi, 2019), which is related to "the ability to notice, interpret, prepare for, and consistently to contain and recover from adversity" (Kutsch et al., 2015). The assumption in most definitions of project resilience is that all project stakeholders can react to adversity in the same way as a team (Pavez et al., 2021; Stoverink et al., 2020). However, this isn't the case in the reality of construction projects. Adverse events affect project stakeholders (e.g., owners, architects, contractors, and suppliers) differently, in which the extent to which project stakeholders are capable or willing to respond and adapt to adversity varies. In the face of the COVID-19 pandemic, where resources are likely to be limited and time is of the essence, project stakeholders who may have conflicting interests for resources and survival may not be able to cooperate to overcome issues.

In such adverse situations, partnering, which is the strategy that creates a trust and win-win environment among all construction parties, can mitigate the adversarial relationships among stakeholders (Construction Industry Institute [CII], 1991; Brown et al., 2017). Boundary activities, which refer to "the actions to establish linkages and manage interactions with parties in the external environment" (Ancona & Caldwell, 1990; Marrone, 2010), can also be salient in dealing with crises. However, few studies have explored the relationships between partnering, boundary activities, and project resilience. Against this background, this study examines how partnering and boundary activities among project stakeholders can influence project resilience and consequently affect project performance. This study contributes to the literature on project management and resilience by revealing how stakeholder interactions may boost project resilience. Understanding the key drivers of project resilience also helps projects to prepare and respond to unexpected disruptive events that may occur in the future.

This research makes significant contributions to the field of resilience, particularly by expanding the resilience concept to the project level, as suggested by Naderpajouh et al. (2020). It offers fresh insights into fostering project resilience, empirically establishing the link between partnering, boundary activities, and project resilience. For practitioners, this study highlights the importance of partnering and boundary activities in constructing resilience within a project. It suggests improving collaboration in partnerships can enable smoother resource and information exchange, as well as coordination beyond organizational limits, thus contributing to a more resilient construction project. It's crucial for project stakeholders to maintain a positive outlook on their collaborative relationships and adhere to a win-win approach, even in challenging times.

The organization of this paper is outlined below. Following this section, we delve into a review of existing research in project resilience, boundary activities, and partnering. Subsequently, we introduce a theoretical model for this study along with the associated research hypotheses. The section thereafter details the research methodology employed, encompassing the sample selection, survey instruments, and analytical techniques. This is followed by a presentation of the analysis findings. The paper concludes with a discussion on both the theoretical and practical contributions of the research, its limitations, and potential avenues for future research.

2. Theoretical background

2.1. Project resilience

Construction projects comprise inherent vulnerabilities and risks that can lead to disruption to project, and in many cases, the failure of the entire project (Naderpajouh et al., 2020). Project risk management is responsible for dealing with disruptions by identifying, preventing, and reducing the adverse impacts to ensure project success (Project Management Institute [PMI], 2017). However, these practices often focus on identifying the sources of disruptions and reducing vulnerabilities without developing the capacity to recover from their negative consequences (Schroeder & Hatton, 2012). The notion of resilience has been proposed to be integrated into project management to overcome this limitation (Naderpajouh et al., 2020; Kutsch et al., 2015; Rahi, 2019; Lim et al., 2021).

Resilience refers to the ability of a system or its members to anticipate, absorb, accommodate, adapt to, and recover from the effects of shocks and stresses timely and efficiently (Kutsch et al., 2015). The term "resilience" is derived from the Latin word "resilio," which means to "bounce back" (Klein et al., 2003). Resilience is the system's ability to self-organize and preserve or quickly restore its functions even under the effects of adverse events, which differs from risk management that focuses on prevention (Lim et al., 2021).

Resilience has become one of the frontier research hotspots in recent years and has been extensively studied in the fields of ecology (Holling, 1973), psychology (Coutu, 2002), engineering (Gunderson & Pritchard, 2002; Choi et al., 2019), and organization science (Vogus & Sutcliffe, 2007; Wood et al., 2019), especially after the occurrence of COVID-19 crises, an unprecedented event in recent history. A massive study has been published on COVID-19 related uncertainties and challenges that were experienced on construction projects. For example, the reported adverse effects of the construction projects and industries worldwide comprised (1) delays and suspensions of existing projects; (2) cancellation of planned and new projects; (3) limited ability of supply chain; (4) reduction in productivity rates; (5) labor or workforce issues including shortage of labor, protection of workers, and decreased worker power; (6) material price escalations, and other financial problems (Alsharef et al., 2021). These negative influences can affect project performance and even lead to project failure.

In the face of such unprecedented crises, project resilience becomes a critical capability to ensure a project's seamless recovery from the pandemic and desired project performance. Despite its rising recognition, project resilience is still relatively new (Rahi, 2019). Described as "the capacity to organize under a variety of scenarios, including disruptions in the form of shocks or stressors" (Naderpajouh et al., 2020), project resilience depends on organizational resources and capabilities and cross-boundary activities between organizations within the project team (Linnenluecke, 2015). Project resilience can be understood as a multifaceted capability that involves mitigating risks through anticipation, adapting to changes, and recovering from disruptions (Madni & Jackson, 2009), which affects project performance. Apart from the disruption and challenges to the normal project operation, unexpected crises such as COVID-19 may also bring new short-term and long-term opportunities to construction projects, which can improve project performance if the project team have the ability to bounce back and learn from setbacks or challenges (i.e., project resilience) (Raoufi & Fayek, 2022). For example, to overcome the difficulties caused by the COVID-19, some projects used remote management applications and technologies such as online communication and cloud computing to keep the project operate (Assaad & El-adaway, 2021). Raoufi and Fayek (2022) identify the most effective mitigation actions to help construction organizations operate during the pandemics such as regularly monitoring for public health/government announcements.

Thus, we hypothesize that:

H1: *Project resilience is positively associated with project performance.*

2.2. Boundary activities

Boundaries are the invisible lines that separate one entity, activity, or process from another and might hinder managing changes and risks in a project (O'Toole & Foley, 2003). Boundary activities in construction projects encompass the following. First is resource and information acquisition. For example, contractors must work based on technical drawings collected from architects (Shen et al., 2021). Second is information dissemination. This task comprises updating external groups about the organization's operations and progress. For example, as construction activities are highly interdependent and subject to change, designers and contractors should immediately update technical information to ensure the accuracy and consistency of information (Tang et al., 2006). Third is coordination and negotiation, which aim at dealing with technical and managerial issues. These activities comprise communicating design issues with outsiders and obtaining feedback, and coordinating and negotiating with others to handle disruptions and crises.

Proactive boundary activities can be conducted to prepare and mitigate risks or crises (Trump & Linkov, 2020; Wang & Pitsis, 2020). However, most adversity crises cannot be predicted, which demands a system's ability to recuperate over time (Williams et al., 2017). When a construction project encounters unexpected risks or crises such as the COVID-19 pandemic, some project stakeholders may be may not be affected, whereas others may be at risk. Consequently, whether a project can overcome the crises largely depends on how these stakeholders are linked and how they coordinate (Kahn et al., 2016). Interdependent creeping disruptions (e.g., undetected design errors, or changes in projects, and misunderstanding between project participants) commonly occur. Such crises necessitate boundary activities to promote urgency among project members.

In the context of crises where resources are scarce, it is suggested that project teams tend to engage in cross-boundary activities actively than those operating in a resource-abundant situation (Shen et al., 2022). Acute need for necessary resources in response to crises can motivate them to seek for external opportunities (Faraj & Yan, 2009). Organizations must engage in a set of organizational boundary activities, including exchanging information and coordinating with stakeholders to maintain function and thrive in the face of shocks and stressors (Du & Pan, 2013). Through boundary activities, teams acquire additional resources and information outside the organization to survive in the adversity. Through boundary reinforcement, teams emphasize the primacy of the project team, motivate members to commit to project tasks, and strengthen their resolve as they adapt to and recover from adversities.

Resilient projects demand the capacity to adjust to the volatile and fast-paced changes positively by enlarging informational inputs and reconfiguring resources through timely cross-boundary communication (Vogus & Sutcliffe, 2007). Under challenging conditions, project stakeholders with high task interdependence must coordinate efforts to achieve common goals (Shen et al., 2021). Boundary activities can spark new connections with distant partners (Harvey et al., 2014) and improve resource, support, and information scouting (Faraj & Xiao, 2006). For instance, when material delivery was delayed due to the supply chain disruption during COVID-19 pandemic, contractors, in consultation with architects and designers, quickly identified alternative materials and equipment that local suppliers and manufacturers can deliver to reduce project delays (Alsharef et al., 2021). Teams that perform effective boundary activities can gain information and resources and buffer external demands (Ancona & Caldwell, 1990). Therefore, we propose the following hypothesis:

H2a: *Boundary activities are positively associated with project resilience.*

Project participants interact with stakeholders both within and outside their organization (Ancona & Caldwell, 1990). Project participants need to perform a series of boundary activities to achieve the desired project performance (Linnenluecke, 2015). Effective boundary activities among key project stakeholders boost team and organizational effectiveness (Marrone et al., 2007), guard against outside threats (Aldrich & Herker, 1976), and facilitate knowledge transfer (Jesiek et al., 2018) and innovation (Collien, 2021).

Smooth boundary activities among project stakeholders are critical to reaching greater project performance (Ancona & Caldwell, 1990; Marrone et al., 2007). With adequate boundary activities among stakeholders while dealing with disruptions, they are expected to understand each other's needs and share a common ground to prevent project delay and cost overrun from poor communication and coordination (Shen et al., 2021). Cross-boundary coordinators connect related parties and highlight their dynamic dependencies. With mutual understanding across various settings, they efficiently respond to adversities by engaging parties in reaching solutions, thereby improving project performance (Collien, 2021). Frequent and timely cross-boundary communication can better engage project participants for efficient decision-making and problem solving in inter-organizational challenges (Marrone, 2010), which also improve project performance. Thus, we propose the following:

H2b: *Boundary activities are positively associated with project performance.*

2.3. Partnering

As a form of relational governance, partnering changes adversarial relations by creating a win-win situation and collaborative spirit (CII, 1991). Although formal governance can directly drive interactions across organizational boundaries (Shen et al., 2021), poor coordination and conflicts between project stakeholders are prevalent because their goals and interests are sometimes misaligned (Tang et al., 2006; Costa et al., 2019). For example, some clients pressure contractors by setting unreasonable contract terms and compressing project schedules, whereas some contractors intend to increase profits by using inferior materials and substandard products. Partnering may reduce such problems. A communication protocol is critical to facilitate boundary activities (Marrone et al., 2007; Du & Pan, 2013). Trust-based partnering can facilitate organizational boundaries to become permeable, which encourages inter-organizational boundary activities (Shen et al., 2017). Project participants share knowledge and information and work toward their common goals (Crowley & Karim, 1995). Thus, we propose the following:

H3a: *Partnering is positively associated with boundary activities.*

Partnering is closely related to the notions of resilience. The win-win philosophy of partnering can motivate project stakeholders to openly share the latest information and important resources (Tang et al., 2006), which helps respond to adversities and recover from the disruptions. All projects, particularly complex ones, have risks (Osipova, 2015). Project participants must manage the design, procurement, construction, and economic and technical issues to avoid delays and cost overrun due to the complexity of construction projects (Wang et al., 2016a). In risk management, proactive and systematic risk identification, effective negotiation, and timely problem solving rely relevant information. Research suggests partnering to facilitate risk management by integrating external information from stakeholders and improving win-win interactions (Wang et al., 2016a).

In addition to risk management, it is also essential for project teams to be able to respond to unexpected disruptions. For example, during the emergency response to Hurricane Harvey, effective stakeholder collaboration is critical for maintaining the functionality of infrastructure systems (Li & Ji, 2021). This process comprises acquiring specialists (Nowell et al., 2018), valuable resources (Sagun et al., 2009), and the exchange of information and knowledge (Steelman et al., 2014). A trust-based partnering relationship may encourage active boundary activities to manage project adversities. A resilient project allows stakeholders to maintain and improve performance through flexible and systemic approaches (Rahi, 2019). For instance, architects and designers with whom contractors have built strong, trusted relationships were more likely to adjust the design and use alternative materials and equipment quickly when the supply chain was interrupted during the COVID-19 outbreak. Local suppliers and manufacturers who had worked well with contractors in previous projects were also prioritized (Assaad & El-adaway, 2021). A prompt collective response helps maintain project functionality in the face of disruptions and reduces cost overrun and project delays. Thus, we propose that:

H3b: *Partnering is positively associated with project resilience.*

Trust, openness, and communication, which are the main elements of partnering, are key factors of project success (Shen et al., 2021; Wang et al., 2016b). During the COVID-19 pandemic, mutual trust and openness between stakeholders can reduce avoidable disagreement and rework expenses (Shen et al., 2017). Partnering encourages project participants to support each other in responding to crises by proactively providing critical resources that can improve project performance or adjust project objectives. Effective partnerships encourage flexibility in product design and project delivery, thereby reducing the costs and risks from late adaptation due to resource constraints or customer needs (Gil & Tether, 2011). Thus, we propose the following hypothesis:

H3c: *Partnering is positively associated with project performance.*

On the basis of the aforementioned hypotheses, we propose a theoretical model, as shown in Figure 1.

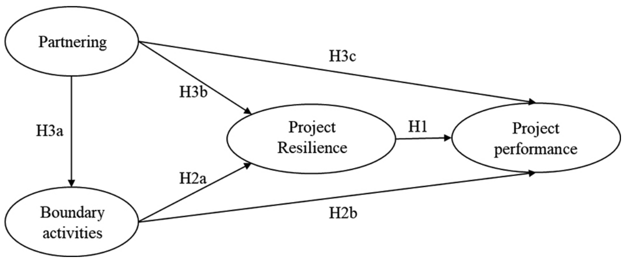


Figure 1. Hypothesized model of project resilience

As explained previously, partnering and boundary activities affect project resilience. The key to project resilience is the project team's ability to integrate and coordinate limited resources through cross-boundary interactions and improved social relationships with its partners. Partnering and boundary activities can boost project performance, and it is likely that this happens through the mediating effects of project resilience.

3. Methodologies

3.1. Data collection

To test the theoretical model in the context of the COVID-19 pandemic, a web-based questionnaire survey was administered in January 2021 to 172 projects in the Chinese construction industry. The managers who were working on the construction projects during the outbreak of the COVID-19 pandemic period in China (between late January 2020 and April 2020) were chosen as respondents in this study. The sudden hit of the COVID-19 epidemic initiated a lockdown policy in most regions of China. Most construction projects suffered from significant delays or other performance problems due to the shortage of workers, materials, and equipment. The researchers first contacted the headquarters of 82 Chinese companies in the construction industry. Then, the administrators of these companies distributed the questionnaires to the potential qualified respondents by email.

Respondents were asked to consider answering the survey questions about one of their recent completed construction projects during the lockdowns of the COVID-19 pandemic period in China, which were specified as the time between late January 2020 and April 2020 in the questionnaire. Only certain workforces are allowed during the lockdown period, including construction projects. The questionnaire comprises two sections: 1) the respondents' personal information (e.g., working experience) and general information of one recent project they had worked on in the strict lockdowns (e.g., project duration and project type); 2) the items in the conceptual model, which will be described in the following section.

A total of 495 valid responses were finally obtained, among which 76.0% were from contractors, 15.6% were from owners, and 8.4% were from consultants and suppliers. The survey respondents reported an average of 13.67 years of construction project management experience. As shown in Table 1, the collected questionnaires were from 172 construction projects from 82 Chinese companies, covering a broad range of location, duration, and contract price. These projects are located in provinces of Beijing, Guangdong, Sichuan, Hubei, Jiangsu, Zhejiang, Liaoning, Shaanxi, Shandong, Inner Mongolia, and Chongqing in China. Most sample projects are building projects (76.4%), followed by infrastructure projects (13.7%) and transportation projects (3.4%).

3.2. Measures

Partnering was measured by adopting from Du et al. (2016) and Tang et al. (2006). Du et al. (2016) found critical success factors (CSFs) of partnering for construction project management. Due to these CSFs, six questionnaire items were used to examine the partnering construct in the present model.

Boundary activities were measured by adapting from Faraj and Yan (2009) and Shen et al. (2021). Faraj and Yan (2009) proposed three boundary activities; namely, boundary spanning, buffering, and reinforcement. Shen et al. (2021) further developed a three-item scale based on these activities in the construction project context. We used this scale to examine the construct of boundary activities in the model.

The measurement of project resilience was adapted from Kutsch et al. (2015), but tailored to fit the context of COVID-19. Following Kutsch's et al. (2015) definition of project resilience as the ability to prepare, respond to, and recover from hazards. Each construct was measured by three items.

Lastly, project performance was measured by whether the project meets the original expectations of quality, schedule, and budget, under the COVID-19 pandemic. All items were rated on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree).

3.3. Data analyses

Structural equation modeling (SEM) was performed to examine the hypothesized model. As a statistical method, SEM is suitable for testing complex interrelationships among multi-variables (Jöreskog & Sörbom, 1996) because not only does it enable the simultaneous and integrative estimation of the interrelationships among independent and dependent variables, but also enables explicit estimation of both random error and systematic error (Bagozzi & Yi, 2012). Because our theoretical model encompasses four mediating interrelationships, SEM is an appropriate method to test the multi mediation process between dependent variables (Bagozzi & Yi, 2012). According to Hair et al. (2010), a sample size of 150 for a model with six constructs would be adequate to obtain convergent and appropriate results. Consequently, the sample size in this research was sufficient for SEM.

Before assessing the interrelationships between constructs, confirmatory factor analysis (CFA) was initially conducted to ensure that the measurement model can measure the constructs accurately. An adequate measurement model needs to achieve convergent validity by the factor loadings (FL) of each construct item above 0.5, composite reliability (CR) above the 0.7 threshold value, and an average variance extracted (AVE) above the 0.5 threshold value (Hair et al., 2010). The measurement model should also achieve a satisfactory discriminant validity assessed by heterotrait–monotrait ratio of correlations (HTMT) not larger than 0.9 (Henseler et al., 2015). Multicollinearity issue and common method bias among constructs in the model were also examined. Once the measurement model met satisfactory criteria, the structural model was assessed by using the goodness-of-fit indices. The ratio of Chi-square (χ^2) to its degree of freedom (df) (χ^2/df) must be lower than 3.0 to achieve a good model fit, which indicates an acceptable fit between the hypothetical model and the sample data (Hair et al., 2010; Hu & Bentler, 1999). Root

Table 1. Characteristics of sample projects

Duration	Percentage	Contract price	Percentage	Project type	Percentage
< 1 year	5.2%	< 50 million RMB	8.1%	Building	76.4%
1–2 years	20.9%	50–100 million RMB	2.9%	Infrastructure	13.7%
2–3years	43.6%	100–500 million RMB	50.0%	Transportation	3.4%
> 3 years	30.2%	500 million–1 billion RMB	18.6%	Others	6.5
		> 1 billion RMB	20.3%		

Note: $^{**}p < 0.01$.

mean square error of approximation (RMSEA) was used as a measure of absolute fit, and comparative fit index (CFI), normed fit index (NFI) and Tucker–Lewis index (TLI) were used as indices of incremental fit. The recommended values for a good model fit are greater than 0.90 for CFI, NFI, and TLI, and less than 0.08 for RMSEA (Hu & Bentler, 1999; Schreiber et al., 2006). Hypotheses were further examined using SPSS Statistics 23 and IBM SPSS Amos 26.

To enhance the reliability of the analysis outcomes, this study employed a bootstrapping sampling approach. This method was used for generating bias-corrected confidence intervals for the mediation relationships and for determining the significance of the mediated paths, as suggested by MacKinnon et al. (2004).

4. Results

4.1. Descriptive statistics

Table 2 displays the means, standard deviations, and intercorrelation matrix of the constructs in the proposed model. All mean scores range between 4.444 and 4.608, indicating an overall positive response to the constructs. Partnering, boundary activities, and project resilience are positively correlated with project performance (correlation coefficients ranging from 0.564 to 0.670). Three main constructs under project resilience (i.e., preparedness, response, and recovery) are significantly correlated with one another. A normality test was also conducted and found skewness values greater than 3 and kurtosis values greater than 10, which indicates no severe violation of normality assumption, as Kline (2005) recommended.

4.2. Measurement model assessment (CFA)

Before examining the hypothesized causal relationships between factors, CFA was performed to validate the convergent and discriminant validities of the measurement model. Convergent validity was validated by standardized FL (FL > 0.5), composite reliability test (CR > 0.7), and AVE (AVE > 0.5). Items PN7–PN10 have FL of below 0.5 and were eliminated. Table 3 shows all the remaining items with FL of above 0.5, which indicates practical significance. Each construct presented satisfactory CR, with a value greater than the recommended minimum threshold of 0.7. AVE also showed standardized loading estimates above 0.5, which indicated strong convergent validity (Hair et al., 2010). Discriminant validity was assessed using HTMT. Table 4 shows that the HTMT correlation matrix for the constructs showed values below the maximum threshold of 0.9, as recommended by Henseler et al. (2015), and achieved adequacy for discriminant validity. The constructs of the hypothesized model were considered adequate with FL, CR, AVE, and discriminant validity at the item and construct levels. The measurement model achieved a good model fit, with $\chi^2 = 397.617$ ($p < 0.001$), $\chi^2/df = 2.298$, CFI = 0.978, NIF = 0.963, TL = 0.974, and RMSEA = 0.051.

As the present study used a single data collection method, common method variance was examined. Unmeasured latent method factor was used to capture common latent factors (CLFs) among all observed variables in the CFA model by restricting paths to be equal and the CLF to be 1. The common variance (the square of the common factor of each path before standardization) is 2%, which is lower than the threshold of 50% (Eichhorn, 2014). A standardized regression weight comparison was then conducted between models with and without CLF, which yielded a significant difference greater than the threshold of 0.20 (Podsakoff et al., 2003). Therefore, the common method variance was detected, and CLFs were retained by imputing composites from factor scores before the structural model.

4.3. Structural model assessment

The structural model was assessed with CLF-adjusted constructs. The structural model achieved a good model fit, with $\chi^2 = 475.998$ ($p < 0.001$), $\chi^2/df = 2.736$, CFI = 0.971, NIF = 0.955, TLI = 0.965, and RMSEA = 0.051. The hypotheses were further examined.

4.3.1. Direct effect

After running a bootstrap procedure with 5,000 subsamples, the results yielded several significant direct relationships among the variables, as illustrated in Figure 2.

The results revealed that project resilience has a significantly positive influence on project performance ($\beta = 0.192$, $p < 0.001$), thus supporting Hypothesis 1 (H1). The coefficients of the paths from boundary activities to project resilience ($\beta = 0.335$, $p < 0.001$) and to project performance ($\beta = 0.307$, $p < 0.01$) were significant, supporting Hypotheses 2a and 2b, respectively. The path coefficients from partnering to boundary activities ($\beta = 0.906$, $p < 0.001$), to project resilience ($\beta = 0.452$, $p < 0.001$), and to project performance ($\beta = 0.302$, $p < 0.01$) were significant, thereby supporting Hypotheses 3a, 3b, and 3c, respectively.

Table 2. Descriptive statistics and intercorrelation matrix of construct items

	Mean	Std. Deviation	1	2	3	4	5	6
1. Partnering	4.608	0.569	1.000					
2. Boundary activities	4.517	0.636	0.813**	1.000				
3. Preparedness	4.599	0.635	0.667**	.580**	1.000			
4. Response	4.607	0.632	0.699**	.646**	0.834**	1.000		
5. Recovery	4.548	0.668	0.658**	.625**	0.776**	0.849**	1.000	
6. Project performance	4.444	0.687	0.670**	.629**	0.564**	0.569**	0.574**	1.000

Table 3. Measurement items, factor loading, validity, and reliability

Construct	Item	Description	Factor Loading	CR	AVE
Partnering (PN)	PN1	We coordinated all partners to reach an agreement on the project objectives and work together to achieve them.	0.846	0.948	0.752
	PN2	We hold a positive attitude towards partners.	0.844		
	PN3	We created an atmosphere of mutual openness.	0.852		
	PN4	We established trust with all partners.	0.894		
	PN5	We kept our commitment to all partners.	0.907		
	PN6	We established sound communication channels between partner organizations.	0.859		
Boundary activities (BA)	BA1	Our organization frequently interacted with external organizations in order to obtain important information, resources and support.	0.777	0.870	0.690
	BA2	Our organization coordinated with other stakeholders to achieve common goals.	0.840		
	BA3	Our organization improved members' commitment of the organization by increasing members' boundary awareness and shaping the organizational identity.	0.873		
Project resilience (PRE)					
Preparedness (PR)	PR1	The project team can effectively identify potential risks in the project and the extent of their impact.	0.811	0.961	0.735
	PR2	During the project planning phase, the project team developed risk response measures.	0.793		
	PR3	The project team was able to continuously monitor risk sources during project execution.	0.814		
Response (RS)	RS1	During the outbreak of COVID-19, the project team was able to respond quickly.	0.865		
	RS2	During the outbreak of COVID-19, the project team was able to respond adequately and effectively.	0.916		
	RS3	During the outbreak of COVID-19, the project team was able to adjust flexibly to contingencies.	0.919		
Recovery (RC)	RC1	With the outbreak under control, the project team was able to return to normal in a short time.	0.869		
	RC2	With the outbreak under control, the project team was able to recover from the crisis at a low cost.	0.841		
	RC3	With the outbreak under control, the project team was able to reduce the damage it caused.	0.779		
Project performance (PP)	PP1	The quality of the project outcome met the requirements.	0.751	0.859	0.670
	PP2	The project schedule met the requirements.	0.851		
	PP3	The project budget plan met the requirements.	0.850		

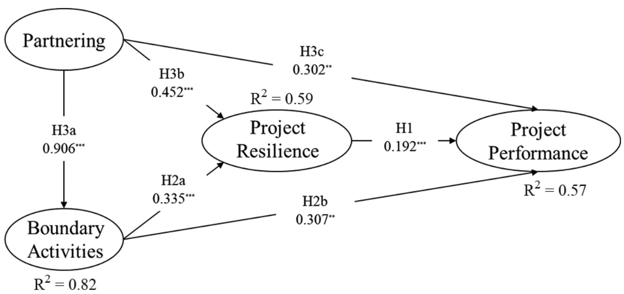
It is estimated that the three predictors in the model, namely partnering, boundary activities, and project resilience, explain 57% of the variance in project performance (R^2 = 0.57). The results indicated that partnering plays a significant role in enhancing project resilience through boundary activities, which in turn affects project performance during the COVID-19 pandemic.

4.3.2. Mediation effect

We performed mediation analysis by examining the magnitude and the significance level of three sets of mediation effects in the final model (Wang et al., 2023): (1) the mediation effects of partnering on project performance through boundary activities and/or project resilience; (2) the mediation effects of partnering on project resilience through boundary activities; and (3) the mediation effects of boundary activities on project performance through project resilience. The bootstrapping estimates, as shown in Table 5, calculate the magnitude of mediation as the product of all standardized path coefficients of the vari-

Table 4. Discriminant validity by HTMT

Constructs	1	2	3	4
1. Partnering	–			
2. Boundary activities	0.898	–		
3. Project resilience	0.752	0.723	–	
4. Project performance	0.755	0.743	0.677	–



Notes: Path coefficient and significant value **p < 0.01, ***p < 0.001.

Figure 2. Structural model of project resilience

ables in the mediated path (Hoyle & Kenny, 1999). The p-values in Table 5 indicate that all examined mediation effects are statistically significant. In other words, boundary activities partially mediate the relationship between partnering and project performance. Additionally, project resilience partially mediates the relationship between partnering and project performance, as well as the relationship between boundary activities and project performance.

4.4. Robustness check

As for robustness, we conducted several additional analyses for validation. First, we developed a sequence of nested models and then compared their key model fit indicators to confirm our hypothesis (Anderson & Gerbing 1988). This process involved constructing seven alternative models by altering the paths between variables, followed by chi-square difference tests to determine if these modifications significantly enhanced the model's fit to the data. These model adjustments were grounded in existing theoretical frameworks that offered alternative, yet viable, explanations. Following Wang et al. (2023) and Pavez et al. (2021), we analyzed the path coefficients and evaluated the chi-square differences among these nested models, as shown in Table 6.

Initially, we evaluated the Baseline Model depicted in Figure 2 against Model 1 to assess if adding a direct effect from partnering to project performance improved the model. The comparison indicated significant differences ($\Delta\chi^2$ (1) = 5.946, $p < 0.01$), demonstrating that this additional path notably enhanced the model's overall chi-square and other fit indices compared to the Baseline Model. Similarly, we compared the Baseline Model with Models 2 to 7, where we removed different paths from the chain mediation model (Baseline model). Our results indicated that Models 2 to 7 do not significantly improve the overall model chi-square or improve the other fit indices relative to the Baseline Model. In other words, the nested models have not improved the model fit compared with the proposed model (Baseline Model). Therefore, the hypotheses were corroborated using an alternative analysis procedure.

Table 5. Mediation analysis summary

Indirect effects	Mediated paths	Standardized estimates	Standardized errors	Lower bounds	Upper bounds	p
PN→PP	PN→BA→PP	0.279	0.172	0.004	0.711	0.046
PN→PP	PN→PRE →PP	0.087	0.050	0.017	0.223	0.015
PN→PP	PN→BA→PRE→PP	0.058	0.053	0.001	0.217	0.036
PN→PRE	PN→BA→PRE	0.304	0.151	0.032	0.636	0.029
BA→PP	BA→PRE→PP	0.064	0.057	0.001	0.233	0.038

Notes: PN = Partnering; BA = Boundary activities; PRE = Project resilience; PP = Project performance.

Table 6. Goodness-of-Fit indices of nested models

Model	Paths	$\chi^2(df)$	RMSEA	CFI	TLI	△χ2	△df
Baseline Model	PN→BA→PRE→PP PN→PRE PN→PP BA→PP	475.998(174)	0.051	0.971	0.965	–	–
Model 1	PN→BA→PRE→PP PN→PRE BA→PP	481.944(175)	0.060	0.971	0.965	5.946**	1
Model 2	PN→BA→PRE→PP PN→PRE PN→PP	482.296(175)	0.060	0.971	0.965	6.298**	1
Model 3	BA→PRE→PP PN→PRE PN→PP	1040.203(175)	0.100	0.917	0.900	564.205***	1
Model 4	PN→BA→PRE→PP PN→PRE	562.654(176)	0.067	0.963	0.956	86.656***	2
Model 5	BA→PRE→PP PN→PRE PN→PP	1052.141(176)	0.100	0.916	0.900	576.143***	2
Model 6	BA→PRE→PP PN→PRE BA→PP	1068.520(176)	0.101	0.914	0.898	592.522***	2
Model 7	BA→PRE→PP PN→PRE	1125.551(177)	0.104	0.909	0.892	649.553***	3

Note: **p < 0.01, ***p < 0.001.

4.5. Measurement invariance

Given the notable disparity in sample sizes among different stakeholder groups (i.e., contractors, owners, and consultants) within the collected valid responses, there is a potential impact on the accuracy of variable measurement. To address this, measurement invariance tests were conducted across these stakeholder groups for enhanced accuracy.

As displayed in Table 7, the configural model (M0) demonstrated a reasonably good fit, establishing a solid baseline for subsequent model comparisons. Subsequent testing involved assessing metric invariance (M1), where all factor loadings were constrained to be the same. The comparison between the M0 and M1 showed no significant differences in fit (△CFI ≤ 0.010 and △RMSEA ≤ 0.015, as per Cheung & Rensvold, 2009). A more stringent test, the scalar invariance (M2), was then applied by constraining the item intercepts to be the same across groups. The fit comparison between the M1 and M2 also indicated insignificant differences (△CFI ≤ 0.010 and △RMSEA ≤ 0.015, following Cheung and Rensvold's guidelines). These findings collectively affirm that the measurements of partnering, boundary activities, project resilience, and project performance are equivalent across different stakeholder groups.

5. Discussion and implications

5.1. Discussion

This study examines how partnering and boundary activities among project stakeholders may influence project resilience and project performance.

First, this research underscores the significant impact of project resilience on project performance, delineating three critical pathways from partnering to project performance as outlined in Table 5: 1) partnering → boundary activities → project resilience → project performance; 2) partnering → boundary activities → project performance; and 3) partnering → project resilience → project performance. These pathways illustrate the role of project resilience as a partial mediator between partnering, boundary activities, and project performance. The concept of project resilience underpins the positive correlation between project resilience and performance (Naderpajouh et al., 2020). Numerous studies have explored how resilient organizations or communities withstand acute shocks or crises. Projects, by their nature, face greater adversities such as risk, uncertainty, and crises compared to permanent organizations or communities. A project's performance is contingent upon its capacity to anticipate uncertainties, adapt to changes, and avert disruptions. Some construction projects have demonstrated resilience, maintaining functionality in adverse conditions and minimizing negative impacts. For instance, during the overlapping periods of the COVID-19 outbreak in China and the Chinese Spring Festival in late January 2020, most construction workers were on vacation. The lockdowns in parts of China prevented their return to work. Project teams implemented measures such as chartered buses to facilitate workers' return, addressing the shortage of workers and consequent delays (Wang & Pitsis, 2020). They also explored alternative sources for materials, tools, and equipment to mitigate the risk of project delays (Assaad & El-adaway, 2021), optimized resource allocation to prioritize work on critical segments, established multiple working shifts to catch up with schedule delays while reducing on-site worker density (Wang & Pitsis, 2020), increased process digitization, and conducted meetings and safety trainings online (Alsharef et al., 2021). The ability of a project to rapidly respond, recover, adapt, and maintain its functionality in disruption reflects its resilience, which can significantly influence its performance.

Second, the study reveals that partnering directly impacts project resilience more significantly than boundary activities, underscoring its effectiveness in fostering resilience. Partnering's critical role in enhancing project resilience is highlighted, especially in managing unexpected events during construction delivery (Wang et al., 2016b). It also indirectly affects resilience by driving inter-organizational interactions, such as resource exchange (i.e., boundary activities). Different construction organizations perceive and respond to disruptions and crises differently (Williams et al., 2017). For instance, while project failure is critical for owners, contractors and designers may view it as a more common and manageable risk. Even within partnerships, the extent of leveraging social connectivity and information-sharing to mitigate adversities – a key aspect of project resilience – varies (Williams et al., 2017). The indirect link between partnering and project resilience can be explained through the lens of social capital theory. In construction projects, diverse organizational social capital either enables or restricts resilience. Bonding social capital, prevalent among closely connected organizations, is manifested as higher trust levels and shared norms within projects, fostering effective interactions and resource provision for adverse situation recovery. However, due to the temporary and loosely coupled nature of project teams, bonding social capital's role in project resilience is more about motivating stakeholders to engage in boundary activities rather than directly expediting short-term responses and recovery.

Table 7. Test of measurement invariance

Model	χ^2	df	CFI	△CFI	RMSEA	△RMSEA
Configural invariance (M0)	2006.141	774	0.943	–	0.04	–
Metric invariance (M1)	2047.672	808	0.942	–0.001	0.039	0.001
Scalar invariance (M2)	2087.287	850	0.943	0.001	0.038	–0.001

Effective response and recovery from adverse events are facilitated when project stakeholders engage with others (Linkov & Trump, 2019).

Third, this study confirms that boundary activities enable project teams to achieve desired performance in the face of unexpected disruptions. This aligns with Li and Ji (2021), who noted that resilient infrastructure systems maintenance in natural disasters necessitates inter-organizational collaboration among stakeholders – a form of boundary activity. Boundary activities, including information processing, resource acquisition, project scope negotiation, and managing requirement changes, aid project teams in responding to environmental contingencies (Ancona & Caldwell, 1990). Consistent with prior studies indicating boundary activities' influence on project performance (Shen et al., 2021) under normal circumstances, this research reveals that boundary activities not only directly impact project performance amid disruptions like the COVID-19 pandemic but also influence performance by enhancing project resilience. This indicates that responding to and recovering from sudden, acute disruptions while maintaining project performance is an ongoing process and may not be instantaneously achieved through a collection of external stakeholder activities. During the COVID-19 outbreak, some projects adjusted designs with owners and designers as the imported equipment supply chain was impacted to avert project delays and reduce operational costs. Early-stage projects altered requirements and standards for selecting local suppliers to ensure a stable supply of materials and equipment.

5.2. Theoretical contributions

This study proposes a theoretical model to examine how partnering and boundary activities among project stakeholders influence project resilience and performance, which has theoretical and practical importance. First, this research extends the literature on project resilience by exploring its antecedents (i.e., partnering and boundary activities) and their interplay mechanism to improve project resilience. Existing studies on resilience have emphasized individual organization perspectives (Kutsch et al., 2015; Linkov & Trump, 2019). This study explores resilience at the project level and reveals how it is related to project performance under unforeseen disruptions. By drawing empirical evidence, this study contributes to project resilience literature by advancing the understanding of how to achieve project resilience through enhancing boundary activities and partnering effectively.

Second, this research contributes to the literature on boundary activities by revealing its significant roles on fostering project resilience in the construction context. Most project resilience studies focused on technical system but ignore the critical part of how project stakeholders interact with each other to address the technical system problems. Few previous studies in project management have specifically examined the role of boundary activities per se in the adverse project contexts. By exploring the mediating effects of boundary activities, we determined that boundary activities between project stakeholders can strengthen the project team's ability to recover from a shock or disturbance. This study contributes novel insights into the body of knowledge of boundary activities in the construction context.

Third, this research contributes to the literature on partnering by highlighting its importance in extreme contexts. Although partnering has been recognized as a critical factor of project success (Shen et al., 2021), its roles in project resilience under disruption remains unclear. The findings shed light on understanding the mechanism that relates formal partnering and project resilience, which helps explain why some construction projects exhibited rapid production resumes and on-time delivery even under the negative impacts of the COVID-19 pandemic (e.g., labor and materials shortages) while others failed (Wang et al., 2021).

5.3. Practical implications

This study indicates broad practical implications for construction management. First, the findings provide a novel insight on strategy development for organizations and project participants to improve their ability to prepare, respond, and adapt from shocks, such as the COVID-19 pandemic, and consequently enhance project performance. Enhancing boundary activities has a positive relationship with a higher level of project resilience. These findings recommend the establishment of institutional standards to foster interactions and coordination among project stakeholders. Second, enhancing partnering can facilitate resource or information flow and coordination across organizational boundaries, leading to a more resilient construction project. Therefore, to be more resilient in the increasingly uncertain, changing, and complex environment, project stakeholders must view their cooperation relationships positively and value the win-win philosophy, even during adversities. Therefore, owners and project managers should take measures to enhance the level of mutual trust, openness, and communication between stakeholders constantly, which can help project participants endure and recover from adversities.

6. Conclusions

This study aims to examine the role that partnering and boundary activities play in project resilience, as well as the ways in which the two phenomena relate to project performance. The model has been empirically tested with a questionnaire survey in 172 construction projects from 82 Chinese companies. The results revealed that project resilience can positively influence project performance. Under the impacts of the COVID-19 pandemic, partnering can directly affect project resilience and performance. The effect of partnering on project resilience is partially mediated through boundary activities. Project resilience shows a direct effect on project performance. The findings of this study advances the body of knowledge of resilience in project management by providing insights on project resilience improvement through the perspective of project stakeholder management. The findings also offer practical implications to encourage stakeholder interactions in projects for better resilience to unexpected disruptions.

Several limitations of this research are acknowledged and provide suggestions for future studies. First, the theoretical model developed in this study was tested based on 495 valid questionnaires collected from 82 Chinese companies that participated in 172 construction projects during the COVID-19 pandemic, across a broad range of project characteristics with regard to geographical locations and project types, enabling effective reduction of bias of selecting samples. Future studies may take on a case study to focus on partnership and boundary activities between the participants within a specific project and examine their influence on project resilience and performance. Second, the data collected in this study was cross-sectional, while the findings could be limited from the different levels of effect on project performance as the results of disruption at different construction phases and should be considered in the future study. Third, this research only considers partnering as a general relational governance strategy, which comprises constructs such as trust, communication, and common goal. In the future study, researchers can assess the construct of partnering in a more rigorous way by asking whether partnering strategies were formally utilized in the projects. Lastly, this study only focused on the roles of partnering and boundary activities on project resilience under the COVID-19 pandemic. While the pandemic has caused adverse impact to construction projects such as delays and suspensions of projects, supply chain disruption, labor and workforce issues, and material price escalation, other disruptive events such as earthquakes or floods may also share similar challenges to construction projects. Future studies exploring more factors of project resilience in various disruptive events are encouraged.

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Author contributions

Wenxin SHEN and Huey Wen LIM conceived the study and were responsible for the design and development of the data analysis. Dongping FANG were responsible for data collection and revised the manuscripts.

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