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How Do Stakeholder Relationships Affect Construction Project Resilience? Unveiling the Complementary Role of Digitalization

Ping Sang, Ronggui Ding, Tao Sun and Chongzheng Li *

School of Management, Shandong University, Jinan 250100, China; sangping@mail.sdu.edu.cn (P.S.); ding_rgui@sdu.edu.cn (R.D.); suntao@sdu.edu.cn (T.S.)
* Correspondence: li_cz@mail.sdu.edu.cn

Abstract

Unexpected disruptions make it essential to develop construction project resilience. Stakeholder relationships can shape disruption handling and thus influence project resilience, yet their roles remain debated. Drawing on organizational information processing theory, this study revisits the controversy over stakeholder relationships by examining ambidextrous learning as an underlying mechanism and digitalization as a complement. Survey data were collected from 238 construction projects. The results show that stakeholder relationships are positively related to project resilience. Exploratory learning serves as a crucial underlying mechanism, while exploitative learning exerts no significant mediating effect. Digitalization complements stakeholder relationships in facilitating exploratory learning, thereby supporting project resilience. Theoretically, this study clarifies the role of stakeholder relationships as a critical network-level enabler of project resilience, reveals the distinct roles of exploratory and exploitative learning in temporary, disruption-prone collaborations, and uncovers the complementary role of emerging digitalization in project management. Practically, this study provides managerial insights into enhancing construction project resilience against potential disruptions.

Keywords: construction projects; project resilience; stakeholder relationships; ambidextrous learning; digitalization

1. Introduction

Unexpected crises like natural disasters, political conflicts, and epidemics expose construction projects to the threat of disruptions and even terminations [1]. The inherent characteristics of construction projects, including temporary organizational structures, multiple heterogeneous stakeholders, strong task interdependencies, and globalized supply chains, may further increase the likelihood of disruption propagation and amplify their impacts. Traditional risk management, which relies heavily on predefined risk identification and historical experience, proves inadequate in handling unexpected disruptions [2]. The importance of project resilience has gained increasing attention [3,4], defined as "the capability of a project system to prepare for, respond to, and recover from disruptions, or eventually turn into a better state" [5].

A construction project often requires the joint efforts of multiple participants with distinct roles [6]. Stakeholder relationships, characterized by intimacy, interactions, and reciprocal services among project participants, are crucial in handling disruptive events [7]. However, broader project management research has implied both benefits and drawbacks of close stakeholder relationships. On the one hand, closely connected stakeholders tend

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to maintain social solidarity during disruptions [7], sharing resources to develop effective solutions, rather than complaining about each other. On the other hand, strong relationships may foster similar knowledge systems [8], which may lead to "groupthink" and even impair flexible disruption response. These conflicting inferences result in competing expectations regarding whether stakeholder relationships enhance or hinder project resilience.

To clarify the controversy, this study introduces organizational information processing theory (OIPT) as the theoretical lens [9,10]. OIPT claims that organizations should develop information processing capabilities to align with their information processing needs [9], which provides a direct explanation for how stakeholder relationships influence project resilience. In particular, unexpected disruptions are characterized by high environmental uncertainty and task complexity, under which project participants are typically confronted with ambiguous and rapidly changing information needs. Stakeholder relationships may shape information acquisition, sharing, and interpretation, thereby influencing project responses to disruptions.

Ambidextrous learning may leverage stakeholder relationship advantages to enhance information processing capabilities, thereby improving project resilience. Ambidextrous learning refers to the social process whereby project stakeholders learn from each other and learn with each other. It encompasses two dimensions, namely exploratory and exploitative learning [11,12]. The former involves joint efforts to identify and acquire novel information, while the latter emphasizes refining existing knowledge and routines [11]. Both learning approaches may transform relational resources into project resilience, according to OIPT. For instance, exploratory learning may benefit from relationship-specific investment, which in turn broadens information access and enhances crisis perception [13,14]. Meanwhile, exploitative learning enables information analysis by integrating internal knowledge within stakeholder relationships, thereby supporting disruption response decisions [15].

Moreover, through the lens of OIPT, emerging digitalization is recognized to complement stakeholder relationships by mitigating their limitations and reinforcing their advantages [16]. Specifically, digitalization offers anonymity and remote connectivity, enabling stakeholders to access diverse information sources and thus avoid "groupthink" in close relationships. Besides, a high level of digitalization enhances information processing capabilities, such as data analytics, to leverage information shared among close stakeholders. The boundary role of digitalization in clarifying the controversy over stakeholder relationships deserves further research.

Overall, this study intends to investigate whether, how, and when stakeholder relationships improve construction project resilience from the OIPT perspective.

This study makes three contributions. First, it advances project resilience research by exploring the controversial role of stakeholder relationships as a critical network-level antecedent. Second, it provides a novel perspective to distinguish exploitative and exploratory learning in the context of temporary, disruption-prone collaborations. Third, this study advances research on digitalization by uncovering how digitalization complements stakeholder relationships in construction project management.

2. Literature Review

2.1. Construction Project Resilience

Project resilience is defined as the capability of a project system to resist unpredictable disruptions [17]. It has been interpreted as the proactive capability to prepare for disruptive events and the reactive capability to respond to and recover from disruptions or even explore new development paths [5]. This concept departs from risk management, a traditional paradigm that relies heavily on historical experience to assess risk events [2]. Traditional risk management aims to minimize costs by allocating precise resources to

address anticipated risks, which often proves inadequate in unprecedented situations. In contrast, the resilience-based paradigm emphasizes readiness for unforeseen disruptions, even necessitating organizations to commit redundant resources.

Previous studies have explored antecedents of construction project resilience at the individual, single-organization, dual-relationship, and project levels. For example, at the individual level, Ram and Dolla (2023) have confirmed the roles of leadership and visionary capabilities of managers [18]. Within single organizations, owners' financial constraints and contractors' technological capabilities have been identified as critical enablers [19]. At the dual-relationship level, Oliveira et al. (2022) have proposed that owner–contractor communication style influences the capability to adapt to construction project disruptions [20]. Other studies have highlighted project-level enablers, such as risk monitoring and contingency planning [21].

Recently, scholars have noticed the potential effects of network-level factors on project resilience. For example, Yang et al. (2022) have demonstrated that construction project resilience depends on prior collaborative experience among stakeholders [22]. These studies have provided exploratory insights mainly through case-based qualitative analysis, which calls for quantitative testing and empirical support.

2.2. Stakeholder Relationship

A construction project often requires joint efforts among multiple participants, since none of them possesses all the knowledge or capabilities necessary for successful delivery. Stakeholder relationships refer to the social closeness among project participants, characterized by intimacy, interactions, and reciprocal services [7,23]. Unlike formally mandated contractual or supervisory ties, these relationships emerge through repeated and frequent interactions, which often give rise to established collaboration norms and routines [24].

Prior studies have indicated the positive roles of stakeholder relationships [25], which may enhance construction project resilience. For example, strong relationships offer both the convenience and the incentive for exchanging asymmetric information and fine-grained knowledge among parties [26]. Such knowledge integration contributes to developing disruption response solutions that go beyond individual cognitive limits. Furthermore, stakeholder relationships reflect cohesion and solidarity [22], which encourage mutual assistance and collective action when disruptions occur.

However, several studies have cautioned against the potential drawbacks of excessively close relationships. Villena et al. (2011) have noted that close relationships limit access to novel information, as stakeholders act in the same social circles [8]. Moreover, reciprocal obligations in highly embedded relationships may lead to lock-in effects that reduce flexibility [27]. Over-reliance on stakeholder relationships may even foster opportunism due to lax compliance scrutiny. Therefore, it remains unclear whether stakeholder relationships strengthen or diminish construction project resilience.

2.3. OIPT and Ambidextrous Learning

The main premise of OIPT is that an organization's information processing capabilities should fit its information processing needs [28]. Information processing needs are related to environmental uncertainty and task complexity, while capabilities refer to the acquisition, exchange, and interpretation of information in a structured, systematic, and logical way. Projects can be viewed as open information processing systems, in which OIPT has been applied to explain the promotion of innovative solutions through enhanced information processing capabilities [29] and the mitigation of information asymmetry among project stakeholders [30].

Ambidextrous learning, the core construct in this study grounded in OIPT, is defined as the social process whereby project stakeholders learn from each other and learn with each other [14]. Two dimensions of ambidextrous learning have been identified: exploratory learning and exploitative learning [12]. The former involves acquiring external information and identifying new opportunities, whereas the latter refers to the use of existing information and the refinement of organizational routines and paradigms [14]. Both exploratory and exploitative learning, and the balance between them, are essential for project development [12]. Prior studies have noted that exploratory learning contributes to identifying innovations [31] and enhancing new product performance [13], while exploitative learning improves project efficiency [32] and supports strategic decision-making [15].

From the perspective of OIPT, ambidextrous learning may provide a pathway through which stakeholder relationships impact construction project resilience. Relational resources can be fully utilized through exploratory learning to acquire broader information, thereby reducing disruption uncertainty [33]. Meanwhile, by mining and integrating knowledge through stakeholder relationships, exploitative learning improves information processing capabilities to handle project disruptions [15]. Since these two distinct yet interdependent processes compete for scarce resources when dealing with project disruptions, it is necessary to investigate their different roles in the link between stakeholder relationships and construction project resilience.

2.4. Digitalization from OIPT

Digitalization refers to the use of digital technologies that store, transfer, and analyze large amounts of data, thereby improving various processes throughout the project lifecycle [34]. Digital technologies are increasingly adopted in the construction industry to assist project management, such as building information modeling (BIM), Geographic Information Systems (GIS), Management Information Systems (MIS), Radio Frequency Identification (RFID), and immersive media (e.g., VR and AR).

From the perspective of OIPT, digitalization can enhance the information processing capabilities (including information acquisition, exchange, and analysis) of projects and thereby facilitate project development [35]. Concerning information acquisition, digital technologies enable broader access to diverse information due to their anonymity and remote connectivity [36]. Chen et al. (2022) have demonstrated that the integration of GIS and BIM promotes automation in on-site data collection and thus facilitates real-time project monitoring and control [37]. RFID is widely used to track material information, which improves the efficiency of resource utilization and on-site construction [38].

As for information exchange and analysis, digital tools like MIS have been found to facilitate multi-party data transfer and coordination [39], which enables autonomous plan updates in response to design changes or schedule deviations. Immersive media establish the physical–digital interface and facilitate information processing from the physical world. These tools support safety management, risk source identification, and construction site visualization [37].

Furthermore, digitalization is expected to shape the effectiveness of stakeholder relationships due to its strong capabilities in information processing [40]. Faruquee et al. (2021) have theoretically inferred that digitalization can serve as an alternative to relational trust in information sharing and integration [16]. Wang et al. (2022) have also concluded that the BIM-based platform can complement relationships in supporting better information exchange among stakeholders [41]. However, the role of digitalization as a complement to stakeholder relationships is quite complex, especially from the perspective of enhancing project resilience, which deserves further research.

3. Hypothesis Development

3.1. Stakeholder Relationship and Project Resilience

Although overly close stakeholder relationships may reduce efficiency due to redundant governance structures, we argue that their positive effects are still predominant in the context of project disruptions. From a proactive perspective, close relationships alleviate parties' excessive concern about opportunistic behavior, thereby encouraging investment in redundant resources for enhancing project resilience [42]. Besides, intimate parties are more willing to provide early warnings of crises [16], and their tacit agreement ensures consistent interpretations of these warnings [43], which facilitates coordinated proactive actions.

Regarding disruption response and recovery, close relationships foster social solidarity during project disruptions, prompting stakeholders to balance their interests with those of their partners, rather than complaining about each other [22]. Moreover, strong relationships often foster interorganizational routines, i.e., stable patterns of joint actions, through repeated interactions. These routines facilitate integrated, synchronized, and swift response actions to disruptions, thereby accelerating project recovery. Hence, this study suggests that:

H1. *Stakeholder relationships have a positive effect on construction project resilience.*

3.2. Mediating Role of Ambidextrous Learning

Stakeholder relationships are considered to enhance exploratory learning in two ways. First, exploratory learning often requires investments in novel, dedicated tools or procedures, the value of which is largely compromised outside the specific project. This asset specificity may induce stakeholders' concerns about being "held up" [44]. Close relationships mitigate this concern, thereby encouraging stakeholders to commit to exploratory learning [44]. Second, exploratory learning is inherently uncertain and involves experiments and innovations [12]. Close relationships foster a shared willingness to take risks and embrace failures associated with exploration [45]. Thus, this study proposes that:

H2a. *Stakeholder relationships have a positive effect on exploratory learning.*

For exploitative learning, stakeholder relationships function in two ways. On the one hand, strong relationships motivate knowledge exchange, a process emphasized by exploitative learning [46]. Stakeholders are less hesitant to share tacit knowledge, particularly that related to irreplaceable capabilities, with close partners [47]. Well-developed relationships also serve as reliable channels that reduce the time and cost required to access the desired knowledge from partners. On the other hand, stakeholder relationships increase the effectiveness of knowledge utilization. Since utilizing complex knowledge often requires extensive background knowledge, only close partners who have developed sufficient overlap in their knowledge systems can more readily apply complex knowledge to project practice [47]. Thus, this study proposes:

H2b. *Stakeholder relationships have a positive effect on exploitative learning.*

From the OIPT perspective, strengthening information processing capabilities, including information acquisition, exchange, and analysis, is essential to address the high needs triggered by project disruptions [9,33]. Exploratory learning enhances information processing by detecting novel information and identifying new opportunities beyond the project system. Continuous monitoring of environmental dynamics improves threat perception

and enables early disruption warnings. This allows project participants to proactively foster project readiness, for example, by rescheduling processes or expanding resource buffers [5].

For post-disruption response and recovery, exploratory learning builds a diverse reservoir of information and thus supports more informed decision-making during disruptions. Moreover, a project that suffers severe disruptions often struggles to return to its original plan [48]. Exploratory learning could generate breakthrough insights, thereby enabling the project to overcome organizational inertia and bounce forward to a new development trajectory [49].

Given that stakeholder relationships positively influence exploratory learning, as argued in H2a, this study suggests that:

H3a. *Exploratory learning plays a mediating role in the effects of stakeholder relationships on construction project resilience.*

Exploitative learning is inherently incremental, emphasizing the continuous refinement of existing skills, solutions, and processes. This refinement strengthens project preparedness for potential disruptions based on prior experience [50]. In addition, exploitative learning emphasizes the exchange and integration of existing knowledge among stakeholders. The synergy of heterogeneous knowledge enhances the information processing capabilities of construction projects, thereby supporting rational decision-making during and after unexpected disruptions [15].

H2b has stated that stakeholder relationships promote exploitative learning by facilitating the exchange and integration of complex knowledge. Exploitative learning, in turn, strengthens the information processing capabilities to address potential project disruptions. Thus, this study infers that:

H3b. *Exploitative learning plays a mediating role in the effects of stakeholder relationships on construction project resilience.*

3.3. Moderating Role of Digitalization

This study proposes that digitalization amplifies the positive effect of stakeholder relationships on construction project resilience by facilitating resource coordination and crisis warning. The use of digital integration technologies establishes a unified platform with shared standards and interfaces [51]. It becomes easier to identify stakeholders who possess the resources or expertise required to address specific disruptive events. This facilitates resource coordination, especially among close stakeholders who are more willing to commit to handling disruptions [15]. Furthermore, while close relationships encourage stakeholders to alert each other to potential crises [16], communication barriers arising from geographic dispersion may delay the transmission of warning signals. Digital technologies like MIS strengthen connectivity among stakeholders [39], enabling real-time disruption warnings regardless of these barriers [39]. Advanced connectivity also facilitates rapid and synchronized response actions during and after disruptions. Thus, this study suggests that:

H4. *Digitalization positively moderates the effect of stakeholder relationships on construction project resilience.*

Digitalization can enhance the positive roles of stakeholder relationships in ambidextrous learning by compensating for their weaknesses and amplifying their advantages. On the one hand, stakeholders who are overly embedded in close relationships rely on monolithic information sources, thus limiting the generation of new ideas [8]. Digital technologies facilitate access to broader and more diverse information [36]. Besides, digital

technology-enabled communication is characterized by anonymity, allowing participants to identify threats and propose novel insights without interference from others. By broadening information sources and enabling the free expression of novel perspectives, digitalization strengthens the acquisition of diverse external knowledge to fuel experimentation and innovation.

For exploitative learning, although close stakeholders are motivated to share tacit knowledge, its transfer is often hindered by inherent stickiness and complexity [46]. Digitalization offers standardized and codified channels to transfer and retrieve tacit knowledge more easily [36]. Moreover, a high level of digitalization equips organizations with the necessary capabilities, such as data analytics, to leverage the information shared among close stakeholders. Therefore, the following hypotheses are suggested:

H5a. *Digitalization positively moderates the effect of stakeholder relationships on exploratory learning.*

H5b. *Digitalization positively moderates the effect of stakeholder relationships on exploitative learning.*

The conceptual framework of this study is thus established, as shown in Figure 1.

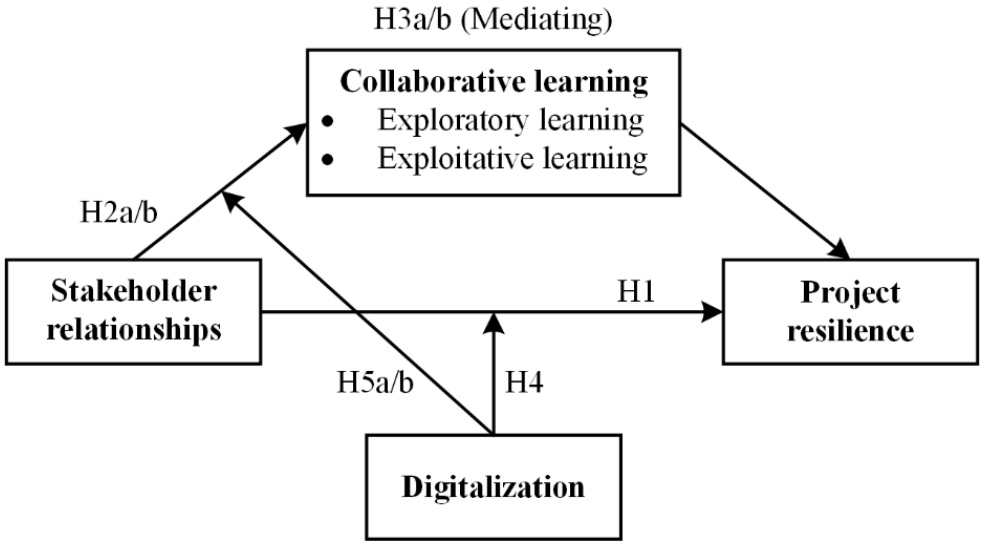


Figure 1. Conceptual framework.

4. Methods

4.1. Measures

Data were collected through a questionnaire survey. The measures of all variables were adapted from established scales in previous studies. To ensure conceptual equivalence and enhance comprehension among Chinese respondents, a back-translation procedure was implemented. All items were measured using a 7-point Likert scale, as detailed in Table 1.

Table 1. Measure reliability and validity analysis.

Constructs and Scale Items	SFL
Stakeholder relationships (Cronbach's α = 0.881; CR = 0.880; AVE =0.710)	
1. Project stakeholders have intimate social relationships with each other.	0.825
2. Project stakeholders often do favors for each other.	0.869
3. There is a sense of "being in the same boat" among project stakeholders.	0.834
Digitalization (Cronbach's α = 0.909; CR = 0.909; AVE = 0.672)	

Table 1. *Cont.*

Constructs and Scale Items	SFL
To what extent are digital technologies used in the following project processes?	
1. Visualizing drawings and 3D models on site (e.g., BIM, immersive media, etc.).	0.886
2. Creating and updating work disposition plans (e.g., BIM, MIS, etc.).	0.894
3. Sharing information between project participants (e.g., BIM, MIS, etc.).	0.940
4. Tracking materials and equipment on site (e.g., RFID, bar codes, QR codes, etc.).	0.637
5. Monitoring the construction environment and progress (e.g., GIS, sensors, etc.).	0.697
Exploratory learning (Cronbach's α = 0.907; CR = 0.913; AVE = 0.725)	
1. Project stakeholders jointly explore the latest industry dynamics, such as policy adjustments and market fluctuations.	0.816
2. Project stakeholders jointly develop or introduce advanced construction processes and technologies.	0.789
3. Project stakeholders jointly acquire novel management skills and methods.	0.917
4. Project stakeholders collaborate to generate breakthrough insights and new solutions to problems.	0.878
Exploitative learning (Cronbach's α = 0.811; CR = 0.810; AVE = 0.588)	
1. Project stakeholders tend to rely on familiar solutions rather than completely new ones.	Deleted
2. Project stakeholders collaborate to refine familiar skills and technologies.	0.742
3. Project stakeholders share existing knowledge to refine the project process.	0.775
4. Project stakeholders constantly improve the application of existing knowledge in project practices.	0.782
Project resilience (Cronbach's α = 0.897; CR = 0.904; AVE = 0.612)	
1. The project is prepared to address unexpected disruptions.	0.831
2. The project is able to reduce the likelihood of disruptions through joint resources.	0.824
3. The project participants monitor processes to avoid potential disruptions in advance.	0.825
4. The project can promptly activate a dedicated team to mitigate crises.	0.674
5. The project can rapidly respond to disruptions.	0.729
6. The project can recover to the original or a better state in a short time.	0.796

Note: SFL = standardized factor loading; CR = composite reliability; AVE = average variance extracted.

4.1.1. Stakeholder Relationships

Stakeholder relationships were measured using three items adapted from Zhou et al. (2014) [52]. Following Rowley et al. (2000) and Levin and Cross (2004), these items assessed the intimacy, interaction, and reciprocity among project stakeholders [26,53].

4.1.2. Digitalization

Digital technologies in construction projects are usually implemented in combination to achieve more coherent outcomes. This study selected five representative digital technologies in Chen et al. (2022), including BIM, GIS, MIS, RFID, and immersive media [37]. Also, five key processes in construction projects were selected [34,37], namely drawing design, planning, information sharing, material tracking, and on-site monitoring. Digitalization was reflected in the extent to which digital technologies are used in these key project processes.

4.1.3. Ambidextrous Learning

Ambidextrous learning was conceptualized as a two-dimensional construct comprising exploratory learning and exploitative learning. Four items for exploratory learning and three items for exploitative learning were adapted from Li et al. (2013), Manley and Chen (2017), and Prieto-Pastor et al. (2018) [13,14,54]. These items were modified slightly to suit the context of construction projects.

4.1.4. Project Resilience

Project resilience was measured using the established items in Yao and Wang (2024), which have demonstrated reliability and validity in the context of construction projects [5].

4.1.5. Control Variables

Five control variables were considered to exclude alternative explanations that may lead to spurious correlations between independent and dependent variables. (1) Project size was measured by contract price in this study. (2) Project duration was controlled for because long-duration projects are more likely to experience disruptions. (3) Background difference was controlled for, as it may influence stakeholder relationships and project resilience. This variable was measured using the item "To what extent do project participants differ in their backgrounds (e.g., geographic location, culture, work styles, construction routines)?" (4) Project complexity was controlled for because it may influence both learning processes and project resilience. This variable was measured using the reverse-coded item "Project tasks can rely on clearly defined and standardized work procedures." (5) Contractor competence was measured using the item "Contractor's expertise is well recognized in the industry," given that competent contractors are more likely to handle non-routine events.

4.2. Sampling and Data Collection

Data were collected from firms that served as owners or general contractors in construction projects. The targeted respondents were middle or senior managers in the firms, such as quality managers and planning managers. They have extensive experience in project management and a comprehensive command of the whole project process, ensuring informed insights regarding the study variables.

A pilot study was conducted to ensure the reliability and validity of the scales before distributing questionnaires. We invited two project management specialists to pilot the original questionnaire and interviewed them about the clarity and relevance. Based on their feedback, we modified several expressions that were difficult for project practitioners to grasp. Then the revised questionnaire was sent to 140 respondents via email and WeChat. After excluding responses that exhibited patterned responses or were completed in an excessively short time (less than 120 s), 104 pilot responses were retained to test scale reliability and validity. The results indicated that deleting the first item of exploitative learning, "project stakeholders tend to look for familiar solutions rather than completely new ones," significantly increased its Cronbach's α from 0.747 to 0.810.

The final questionnaire was distributed through the alumni networks of the authors' institutions, targeting experienced project practitioners in the construction industry. Three criteria were established to identify qualified respondents, including industry (construction), employment status (on the job), and positions (middle or senior project managers). To further ensure data quality, we included a pair of reverse-coded items and a common-sense question to filter out unqualified responses. A total of 245 questionnaires were distributed. After excluding responses that showed patterned responses, too-short completion times (less than 120 s), conflicting answers to the reverse-coded items, or incorrect answers to the common-sense question, 238 valid responses were retained, yielding a valid response rate of 97.1%. Table 2 presents the profiles of the sample projects and the respondents.

Table 2. Sample demographics.

	Frequency	Percentage
Working experience (years)		
<3	7	3.6
3–5	44	22.7
6–8	44	22.7
9–11	47	24.2
>11	52	26.8

Table 2. *Cont.*

	Frequency	Percentage
Project type		
Transportation	24	12.4
Housing engineering	93	47.9
Petrochemical	6	3.1
Electrical	21	10.8
Hydraulic engineering	7	3.6
Others	43	22.1
Contract price (million CNY)		
<50	66	34.0
50–100	41	21.1
100–500	52	26.8
500–1000	16	8.2
>1000	19	9.8
Project duration (years)		
<1	75	31.5
1–3	118	49.6
>3	45	18.9

4.3. Reliability and Validity

The internal consistency and reliability of the multi-item scales were evaluated using SPSS 26.0. As reported in Table 1, Cronbach's α values of all the scales are above the 0.8 benchmark, indicating good reliability.

We assessed the scale validity by conducting confirmatory factor analysis (CFA) using Amos 26.0. The model fit indices ($\chi^2/df = 1.768$, GFI = 0.871, CFI = 0.946, IFI = 0.946, TLI = 0.937, and RMSEA = 0.057) indicate a satisfactory model fit. Standardized factor loadings, average variance extracted (AVE), and composite reliability (CR) are shown in Table 1. All standardized factor loadings exceed the benchmark of 0.5, ranging from 0.637 to 0.940. The AVE for each construct is above the 0.5 threshold, ranging from 0.588 to 0.725. All CR values are above 0.7, ranging from 0.810 to 0.913. Thus, the scales demonstrate good convergent validity. Moreover, as shown in Table 3, the square roots of the AVE values (displayed on the diagonal) are higher than the off-diagonal correlation coefficients, indicating good discriminant validity.

Table 3. Descriptive statistics and correlations.

	Mean	S.D.	SR	DIG	ER	EI	PR
SR	5.342	1.061	**0.843**				
DIG	4.593	1.525	0.381 ***	**0.820**			
ER	5.207	1.157	0.567 ***	0.533 ***	**0.851**		
EI	5.445	0.928	0.613 ***	0.381 ***	0.595 ***	**0.767**	
PR	5.023	1.061	0.615 ***	0.516 ***	0.603 ***	0.538 ***	**0.782**

Note: The square root of AVE on the diagonal is in bold. *** $p < 0.001$. SR = Stakeholder relationships; DIG = Digitalization; ER = Exploratory learning; EI = Exploitative learning; PR = Project resilience.

4.4. Common Method Variance

Since this study employed a questionnaire survey to collect data, common method variance (CMV) may be a concern. To assess this potential issue, we conducted exploratory factor analysis (EFA) with Harman's single-factor test [55]. The results demonstrate that the largest variance explained by a single factor was 29.636%, well below the recommended threshold of 40%.

Furthermore, the latent common method factor approach was conducted [56]. A latent CMV factor was added to the model, allowing all items to load on this factor in addition to their respective theoretical constructs. Compared with the original CFA model, the model fit did not improve significantly after adding the CMV factor: $\chi^2/df = 1.949(\Delta = 0.181)$, GFI $= 0.870(\Delta = -0.001)$, CFI $= 0.936(\Delta = -0.010)$, IFI $= 0.937(\Delta = -0.009)$, TLI $= 0.920(\Delta = -0.017)$, and RMSEA $= 0.063(\Delta = 0.006)$. Thus, common method variance is not a serious issue in this study.

5. Results

This study employed hierarchical regression analysis to test the hypotheses using SPSS 26.0. The variance inflation factor (VIF) was calculated for each explanatory variable and control variable. The results show that all VIF values are below the threshold of 5, indicating no serious concern about multicollinearity.

We tested Hypotheses 1, 2a, 2b, 3a, and 3b using the PROCESS macro. Table 4 summarizes the regression results. Stakeholder relationships have a significant positive effect on project resilience ($\beta = 0.545$, $p < 0.001$), as shown in Model 5. Thus, H1 is supported. Models 3 and 1 confirm the positive effects of stakeholder relationships on exploratory learning ($\beta = 0.537$, $p < 0.001$) and exploitative learning ($\beta = 0.495$, $p < 0.001$), supporting H2a and H2b.

Table 4. Regression results.

Model Variable	Exploitative Learning		Exploratory Learning		Project Resilience		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	2.046 ***	4.892 ***	0.819	4.429 ***	0.887	0.376	2.856 ***
	(0.336)	(0.344)	(0.432)	(0.412)	(0.383)	(0.383)	(0.515)
Size	0.043	0.047	0.046	0.041	−0.031	−0.049	−0.040
	(0.045)	(0.045)	(0.058)	(0.053)	(0.051)	(0.048)	(0.047)
Duration	−0.062	−0.090	0.083	−0.014	0.057	0.042	−0.001
	(0.083)	(0.082)	(0.106)	(0.098)	(0.094)	(0.088)	(0.086)
BD	−0.033	−0.015	0.046	−0.023	0.058	0.046	0.024
	(0.048)	(0.048)	(0.062)	(0.058)	(0.055)	(0.051)	(0.050)
CC	0.135 **	0.116 *	0.192 **	0.125 *	0.173	0.100	0.084
	(0.048)	(0.048)	(0.061)	(0.057)	(0.054)	(0.052)	(0.050)
PC	−0.041	−0.052	−0.038	−0.049	−0.094 *	−0.087 *	−0.069
	(0.046)	(0.045)	(0.058)	(0.056)	(0.046)	(0.044)	(0.045)
SR	0.495 ***	0.438 ***	0.537 ***	0.472 ***	0.546 ***	0.327 ***	0.305 ***
	(0.048)	(0.052)	(0.062)	(0.062)	(0.055)	(0.064)	(0.064)
DIG		0.092 **		0.271 ***			0.148 ***
		(0.034)		(0.041)			(0.039)
SR * DIG		−0.033		0.082 **			0.048 *
		(0.026)		(0.031)			(0.024)
EI						0.133	0.112
						(0.074)	(0.073)
ER						0.282 ***	0.211 ***
						(0.058)	(0.061)
R^2	0.405	0.656	0.367	0.472	0.410	0.492	0.528
F	31.233 ***	24.398 ***	26.425 ***	29.273 ***	31.924 ***	32.023 ***	28.195 ***

Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$. Standard errors are in parentheses. BD = Background difference; CC = Contractor competence; PC = Project complexity.

To test the mediation hypotheses, we used the bootstrapping procedure recommended by Hayes and Preacher (2014) [57]. As displayed in Table 5, stakeholder relationships have a significant indirect effect on project resilience through exploratory learning, whereas the

indirect effect through exploitative learning is not significant. The results support H3a but not H3b.

Table 5. Results of mediating effects.

Path	β	SE	95% CI	Mediating Effect
SR→PR	0.325	0.064	[0.199, 0.452]	—
SR→ER→PR	0.153	0.058	[0.052, 0.277]	Supported
SR→EI→PR	0.067	0.047	[−0.014, 0.170]	Unsupported

Finally, we examined the moderating effects of digitalization using bootstrapping with 5000 resamples. As shown in Table 4, digitalization positively moderates the association between stakeholder relationships and project resilience ($\beta = 0.048$, $p < 0.05$), supporting H4. Digitalization also positively moderates the association between stakeholder relationships and exploratory learning ($\beta = 0.082$, $p < 0.01$), supporting H5a. The simple slope plots are presented in Figure 2, illustrating that the positive effects of stakeholder relationships on both project resilience and exploratory learning are stronger when digitalization is high compared to when it is low. However, the moderating effect of digitalization on the link from stakeholder relationships to exploitative learning (Model 2) is not significant. Thus, H5b is not supported.

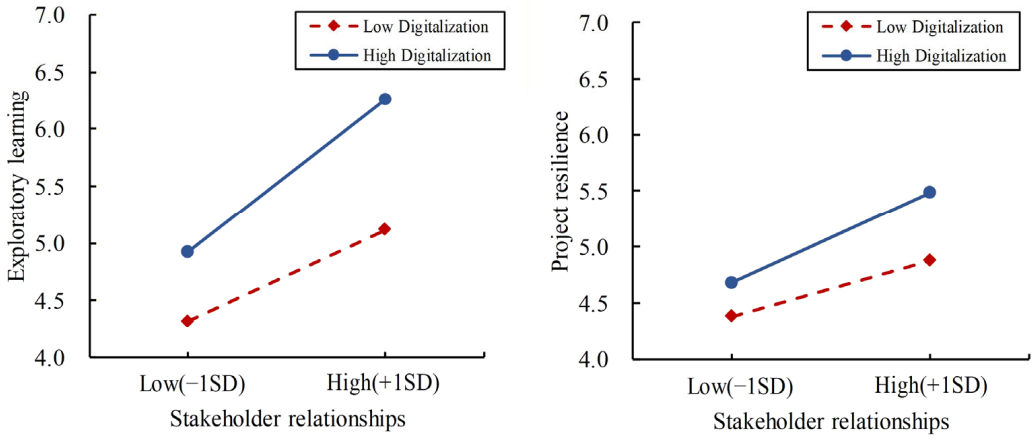


Figure 2. Simple slope plots.

6. Discussion

6.1. Stakeholder Relationship and Project Resilience

Previous studies have suggested both beneficial and adverse consequences of close stakeholder relationships, leaving their role in construction project resilience unclear. Our findings advance the understanding of this debate by showing that stakeholder relationships positively affect project resilience. This conclusion aligns with the qualitative research of Geambasu (2011), who has highlighted that common vision and effective communication embedded in close stakeholder relationships enhance project resilience [58]. Yang et al. (2022) have also identified stakeholder ties as crucial for project disruption response and recovery through a case study [22]. This study provides direct empirical support for these qualitative insights.

Although several studies have noted that close stakeholder relationships may generate governance redundancy, resource inertia, and overlapping communication channels, thereby reducing operational efficiency [59], the benefits of stakeholder relationships still dominate when projects face unexpected disruptive events. As Giezen et al. (2015) have suggested, it is precisely such redundancy that provides the slack resources necessary for

withstanding unforeseen disruptions [60]. This finding suggests that it is inappropriate to discuss the beneficial or adverse roles of stakeholder relationships without considering the research contexts. The distinctions between routine operations and unexpected disruptions provide a possible explanation for the controversy over stakeholder relationships in the literature.

6.2. Mediating Role of Ambidextrous Learning

H2a and H2b are supported in this study, indicating that stakeholder relationships facilitate both exploratory and exploitative learning. The findings provide empirical evidence for the proposition of Sumanarathna et al. (2020) that network ties facilitate exploratory and exploitative learning in project-based organizations [61]. The findings also align with Stock et al. (2021), who have claimed that interorganizational interaction facilitates knowledge sharing from an OIPT perspective and thereby contributes to project performance [62].

The mediating role of exploratory learning between stakeholder relationships and construction project resilience is confirmed (H3a). This result empirically supports the findings of Piperca and Floricel (2023) through a case study [48]. They have argued that project resilience often requires breaking from established routines and pursuing novel insights, especially when severe disruptions hamper the implementation of the original plan [48]. Drawing on OIPT, this study also complements the viewpoint of Love et al. (2016) from the capability perspective, who have underscored the importance of acquiring new knowledge and engaging in routine-breaking behaviors for project delivery [50].

Moreover, stakeholder relationships still exhibit a significant, albeit weakened, effect on construction project resilience after exploratory learning is added to the regression model, as shown in Model 6 in Table 4. This indicates that exploratory learning plays a partial mediating role. Beyond the information processing capabilities outlined by OIPT, additional pathways may transmit the benefits of stakeholder relationships to project resilience, such as resource reconfiguration, the capability of temporary organizations to reconfigure, readjust, and reorganize resources [63].

In contrast, exploitative learning does not exhibit a significant mediating effect (H3b). Although exploitative learning has been confirmed to enhance project efficiency by refining existing routines [45], such incremental improvement may be insufficient for fostering resilience against unprecedented disruptions. From an OIPT perspective, this non-significant finding may reflect a mismatch between the information processing capability developed through exploitative learning and the needs imposed by unexpected disruptions. Specifically, exploitative learning emphasizes refining, integrating, and applying existing knowledge, which is particularly effective when information needs are relatively stable and predictable [12]. However, unexpected disruptions generate novel, ambiguous, and rapidly changing information needs that often exceed the scope of accumulated knowledge and established routines, making exploitative learning less effective in supporting adaptive responses to unprecedented disruptions.

This limitation is further amplified by the temporary and non-repetitive nature of construction projects. Since each construction project is undertaken with unique objectives, stakeholder configurations, and environmental conditions, the "successful" experience derived from previous projects through exploitative learning may be unsuitable when applied to a new project context. Over-reliance on such experience may even induce organizational inertia, thereby hindering the innovative insights and solutions necessary for adaptive recovery. This fundamentally distinguishes project resilience from traditional risk management, which focuses on addressing foreseeable risk events based on historical experience [2]. These limitations of exploitative learning in the temporary, disruption-prone

context of construction projects may offset the benefits proposed in H3b, resulting in a non-significant mediating role.

6.3. Moderating Role of Digitalization

The results demonstrate that digitalization plays a positive moderating role between stakeholder relationships and project resilience (H4). This finding provides empirical support for the theoretical logic that digitalization amplifies the benefits of close relationships in coping with disruptions. By enhancing connectivity and supporting real-time data exchange, digital technologies enable close stakeholders to transmit early crisis warnings and orchestrate synchronized responses regardless of geographic dispersion, thereby reinforcing both proactive and reactive resilience. This finding also extends the theoretical proposition of Faruquee et al. (2021) that digitalization can complement relational resources in building supply chain resilience to the temporary, one-off context of construction projects [16].

Digitalization serves as a key complement that amplifies the positive effect of stakeholder relationships on exploratory learning (H5a), but it does not significantly moderate the link between stakeholder relationships and exploitative learning (H5b). This difference may be attributed to the distinct natures of the two learning approaches. Exploitative learning focuses on refining routines and applying existing knowledge, a process that relies heavily on repeated interaction, shared background, and mutual understanding within close stakeholder relationships. Although digitalization may facilitate knowledge storage, codification, and transfer, its complementary role in further strengthening exploitative learning is limited once relational foundations have been established.

Furthermore, Son et al. (2021) have claimed that digitalization may trigger concerns about data leakage and privacy violations [64], prompting stakeholders to prioritize self-protection over knowledge-sharing, a process crucial for exploitative learning. The high level of familiarity in close relationships may even enable the digitally advantaged party to leverage capability asymmetry to appropriate information without being detected [65]. The potential downsides of digitalization may counteract its expected complementary role stated in H5b, resulting in a non-significant moderating effect.

By contrast, exploratory learning requires capabilities for accessing and acquiring diverse external information, a demand that digital technologies are particularly well-suited to satisfy, thereby amplifying the utility of relational resources for exploration. While digitalization may also dampen stakeholders' willingness to engage in exploration due to its potential dark side in close relationships (similar to its effect on exploitative learning), its role in enhancing exploratory capability still dominates. As Jean and Sinkovics (2010) have concluded, advanced technologies enhance an organization's capability to access novel information and identify new opportunities within strong networks [66].

7. Conclusions

7.1. Theoretical Contributions

This study contributes to research on construction project management in three ways. First, it extends research on the antecedents of project resilience by clarifying the controversial role of stakeholder relationships. Prior studies have associated close stakeholder relationships with both beneficial outcomes and adverse consequences, leaving their effect on project resilience unclear. This study identifies stakeholder relationships as a critical network-level enabler for enhancing construction project resilience, which complements existing antecedents at individual, single-organization, dual-relationship, and project levels. The findings also underscore the importance of considering research con-

texts, such as routine operations versus project disruptions, to explain the mixed roles of stakeholder relationships.

Second, this study provides a novel perspective to distinguish exploratory and exploitative learning by revealing their different roles in the temporary, disruption-prone context of construction projects. Although prior research has confirmed the beneficial effects of both learning approaches under a stable environment, this study indicates that in temporary and disruption-prone project settings, exploratory learning serves as a mediating mechanism linking stakeholder relationships to project resilience, whereas exploitative learning does not exert a significant mediating effect. The finding implies that unexpected project disruptions pose a greater demand for the breakthrough insights, innovation, and flexibility emphasized by exploratory learning, rather than the imitation, refinement, and efficiency involved in exploitative learning.

Third, the study advances research on digitalization by revealing its role as a complement to stakeholder relationships in project management. While previous studies have proposed the complementary potential of emerging digitalization for stakeholder relationships, its actual role remains underexplored. This study demonstrates that digitalization complements stakeholder relationships in facilitating exploratory learning, thereby supporting project resilience. However, its complementary role in strengthening exploitative learning is not supported. The findings suggest that implementing digitalization requires detailed norms and regulations to mitigate its potential negative impacts, especially in temporary and disruption-prone construction projects.

7.2. Managerial Implications

This study provides several practical implications for project managers in the construction industry to cope with unexpected disruptions. First, it highlights the importance of stakeholder relationships for project resilience in disruption-prone contexts, even though close relationships are sometimes viewed as redundant and time-consuming in stable environments. Managers are advised to invest in activities that cultivate intimacy and mutual support among project participants. For instance, informal communication meetings and joint training programs can help participants build personal familiarity that goes beyond formal contractual ties. Project managers can also establish reciprocal assistance mechanisms, such as shared resource pools for critical materials, equipment, or specialized personnel, which encourage stakeholders to support one another when disruptions occur.

Second, this study reveals to managers that exploratory learning is more effective than exploitative learning in transmitting the positive effect of stakeholder relationships on construction project resilience. Managers are advised to bring fresh information into the project system, including industry dynamics, policy adjustments, advanced technologies, and alternative opportunities. They could also allocate dedicated resources to pilot-test innovative solutions or engage external consultants to introduce fresh perspectives that break habitual ways of thinking, rather than focusing solely on incremental improvements to existing methods.

Third, this study highlights the complementary role of digitalization in strengthening the effect of stakeholder relationships on project resilience. Close stakeholder relationships depend on repeated interactions and are therefore difficult to adjust or deepen within a limited project duration. Under such temporal constraints, digitalization offers a practical lever to amplify the resilience benefits of existing relational resources. For example, project teams can use BIM to update work disposition plans and send real-time alerts to all stakeholders when disruptions occur, ensuring that coordinated action is not impeded by communication barriers. RFID and sensor-based monitoring systems can provide all

parties with transparent, real-time visibility into material flows and on-site conditions, thereby reducing information asymmetry and enabling a joint response.

Finally, it is important to note that the complementary role of digitalization is conditional. Project managers are advised to implement digital tools with well-defined safeguards, including clear protocols for data access and intellectual property protection. These safeguards can help prevent concerns such as data leakage or perceived capability asymmetry from undermining the collaborative willingness that close relationships have already established.

7.3. Limitations and Future Research

This study highlights the following limitations and proposes directions for future research. First, the cross-sectional survey design and regression analysis limit the ability to draw definitive causal inferences. Future studies could employ longitudinal or experimental designs to establish stronger causal evidence and capture the dynamic evolution of stakeholder relationships across the project lifecycle. Second, the results indicate that exploratory learning plays a partial mediating role in the link between stakeholder relationships and project resilience. Additional pathways are worth exploring in future studies, such as stakeholder collaboration and resource reconfiguration. Third, treating digitalization as an aggregate construct may mask the heterogeneous effects of different digital technologies. Future studies could classify digital technologies for more detailed research, for example, by distinguishing between networked technologies (e.g., BIM, MIS) and physical–digital interface technologies (e.g., RFID, sensors, immersive media) [36]. Fourth, the data in this study were collected from construction projects in China, which may limit the generalizability of the findings. Future research should extend the study to other institutional and cultural contexts or conduct cross-national comparative studies to examine the boundary conditions of these findings. Lastly, although this study controlled for several project characteristics, other factors may also influence learning processes and project resilience, such as project team size, company ownership structure, or experience of interorganizational cooperation. Future studies are therefore encouraged to incorporate these factors to further validate the robustness of the findings.

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