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EXPLORING THE TECHNOLOGY-ORGANIZATION-ENVIRONMENT CONFIGURATIONS TO ENHANCE STAKEHOLDER COLLABORATION IN THE OFF-SITE CONSTRUCTION PROJECTS

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Abstract. Stakeholder collaboration is critical in empowering off-site construction (OSC) projects to reduce the cost overrun, conflicts and quality problems. Prior studies have explored the factors affecting stakeholder collaboration but focused on the net effects, ignoring their interaction relations. Our study aims to explore the configuration conditions to enhance stakeholder collaboration in OSC projects using fuzzy-set qualitative comparative analysis (fsQCA). 103 valid questionnaires are collected to conduct fsQCA to explore the configurational conditions to achieve the high stakeholder collaboration. The findings reveal that there are no necessary conditions as a bottleneck factor constraining stakeholder collaboration emergence in the OSC projects. Three equivalent configurational conditions are identified to achieve high stakeholder collaboration, referring to environment-driven organizational configuration, technology-organizational configuration, and organizational-driven environment configuration. Our study enriches the literature on the antecedent identification of stakeholder collaboration in the OSC project. It also expands the underlying mechanisms between antecedents and stakeholder collaboration from the configurational perspective. Meanwhile, our study provides practical guidance for policymakers and project managers to make decisions by emphasizing the interaction effects of different project governance mechanisms.

Keywords: off-site construction, stakeholder collaboration, TOE, configuration condition.

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1. Introduction

Off-site construction (OSC) has gained significant attention in the architectural, engineering, and construction (AEC) industry due to its economic, environmental, and energy benefits, which increases productivity, shortens construction timelines, reduces energy consumption, and enhances sustainability (Cao et al., 2015; Heravi et al., 2021; Hong et al., 2016; Kamali et al., 2018). OSC has multiple types, such as prefabricated buildings, modular construction, prefabricated prefinished volumetric construction, etc. (Wong et al., 2017). For OSC projects, precast components are produced in off-site factories, transported, and assembled into a building on site, which reduces material waste and improves energy efficiency (Yang et al., 2021). Key stakeholders of OSC are the clients (defining project scope, budget, and schedule), design firms (providing design drawings and completing the design work), PC manufacturers (providing precast components and assisting with on-site installation), consultant companies (providing project management services and supervision services), general contractors (responsible for on-site construction management) and subcontractors (responsible for professional sub-construction work). Different from on-site conventional construction, stakeholder roles shifted due to close linkages and ambiguous interfaces of the design, production, and construction works. In practice, design works have effects on PC production costs and on-site constructability, which leads to PC manufacturers and general contractors participating in detailed design works to minimize on-site changes and reduce PC production costs (Hu et al., 2019). High interdependence among design, production, and installation tasks intensifies stakeholder collaboration. Inadequate collaboration between PC manufacturers and general contractors may cause logistical issues, assembly errors, and project delays due to the installation process not being smooth (Zhao et al., 2021). In contrast, effective collaboration may remove contract conflict, reduce PC cost and save time. Early involvement of design firms, PC manufacturers, and general contractors can improve the constructability and cost efficiency of the design scheme. General contractors can draw on on-site construction experience to propose improvements in structural layout, process sequencing, and construction methods, thereby avoiding mismatches between PCs and on-site cast-in-place elements and ensuring a reasonable schedule for PC component production (Nesarnobari et al., 2025). Therefore, improving stakeholder collaboration is crucial for enhancing the performance of OSC projects.

Prior studies have explored factors affecting collaboration amongst stakeholders in OSC projects. Compared to conventional on-site construction, OSC faces problems in the technology aspect, such as elevated technical complexity (Pan et al., 2023), substantial correlation among tasks (Jiao & Li, 2018; Zhang et al., 2020), and heightened demand for resource integration pose elevated (Abedi et al., 2016) needs the project teams' collaboration. As a temporary project organization, organizational factors should be stressed on OSC project stakeholder collaboration. In practice, multiple stakeholders focus on the collective commitment at the project level rather than the individual level (Feng et al., 2017; Xue et al., 2022). A robust informal relationship is crucial for multiple stakeholders, with frequent communication (Ma et al., 2023; Pauget & Wald, 2013) and trust (Nasir & Hadikusumo, 2019) being pivotal factors influencing collaboration. Moreover, fair benefit distribution (Chen et al., 2023), risk-sharing mechanisms (Lee et al., 2023), and explicit contractual terms (Yan & Zhang, 2020) constitute essential prerequisites to ensure the stability of collaborative endeavors. While technological and organizational factors operate primarily at the project level, environmental factors also exert external pressures that shape stakeholder interactions. For example, Zhou et al. (2024) identified that industry competition is pivotal as a driving force for stakeholder collaboration in OSC projects. Moreover, regulating pertinent policies, governmental support, and subsidy initiatives (Wang et al., 2021; Wuni & Shen, 2020) also catalyze collaboration in OSC projects.

Although existing studies have explored factors influencing stakeholder collaboration in OSC projects from different perspectives, many focused on their net effect and ignored the configurations. For example, Dou et al. (2019) used regression analysis to identify the relevant influencing factors; Al-Aidrous et al. (2023) and Mao et al. (2015) assessed the significance of factors using empowerment methods. According to the configuration perspective, this narrow scope neglects essential combinations necessary for achieving high stakeholder collaboration and underestimates the complex causal dynamics driving it. For example, Xue et al. (2022) emphasized that, as a complex system involving multiple stakeholders and regulated by market conditions and policies, the factors affecting collaboration in OSC projects are interdependent rather than separate. Effective collaboration in OSC projects necessitates strong internal technical integration, robust interaction mechanisms, and substantial external support. This aligns with the Technology-Organization-Environment (TOE) framework, which posits that introducing new technologies involves interactions among technology, organization, and environment dimensions, influencing outcomes through mutual constraints and interactions (Tornatzky & Fleischer, 1990). Nevertheless, whether a single factor can lead to high stakeholder collaboration remains to be seen, nor is it evident which configuration conditions affect stakeholder collaboration systematically. To fill this research gap, our study aims to explore the configurational effects of TOE factors on stakeholder collaboration in OSC projects from a configuration perspective and addresses three questions:

(1) Are necessary conditions for stakeholder collaboration in OSC projects?
(2) Which configurational conditions are sufficient for stakeholder collaboration in OSC projects?
(3) How can stakeholder collaboration be improved in the OSC projects based on the TOE framework?

2. Theoretical framework

2.1. Stakeholder collaboration in OSC

OSC projects exhibit three characteristics that necessitate stakeholder collaboration. First, OSC involves various independent organizations, such as clients, design firms, PC manufacturers, consultant companies, general contractors and subcontractors, operating across dispersed sites (Hu et al., 2019). Second, OSC projects require tight coordination of sequential processes from design to component production and on-site assembly (Hussein & Zayed, 2021). Third, project outcomes depend on interdependent decision-making between specialized stakeholders with fragmented knowledge bases (Ma et al., 2023). These characteristics create coordination challenges. Unlike traditional on-site construction, OSC demands continuous information exchange between organizations working on separate project phases. The physical separation between design teams, manufacturing facilities, and construction sites further complicates task integration (Li et al., 2022a). Therefore, effective stakeholder collaboration becomes critical to overcome organizational barriers and align distributed operations. Studies indicate that collaboration in OSC can eliminate organizational barriers and integrate internal factors, maximizing the benefits of 1 + 1 > 2 (Xue et al., 2022; Yang et al., 2018).

2.2. TOE framework

Technology-Organization-Environment (TOE) framework, introduced by Tornatzky and Fleischer (1990), is a flexible and practical tool of project management. It posits that the decision to adopt an innovative technique is influenced by factors residing in technical, organizational, and environmental dimensions. Technical dimensions encompass inherent technological characteristics, including technological compatibility and complexity, which impact the feasibility and ease of innovation adoption (Kamali & Hewage, 2016; O'Connor et al., 2016); Organizational dimensions pertain to the organization's structure, culture and attributes, which shape its capacity and readiness for change (Teng et al., 2017; Xue et al., 2018); Environmental dimensions refer to the objective context, encompassing policy environment, market competition and demand, which can act as facilitators or barriers to innovation diffusion (Gan et al., 2018; Li et al., 2016; Liu et al., 2017).

OSC project represents an innovative approach to project delivery that reshapes conventional construction processes. OSC implementation depends on seamless stakeholder collaboration to a large degree. It further constitutes a collaborative innovation, which is essential for the effective adoption of the OSC technique. Prior studies have used the TOE framework to explore the factors affecting the inter-organizational relationships and collaborative innovation (Adade & de Vries, 2025; Li et al., 2022b; Malik et al., 2021), which provide the practical views for our study. Technological factors (i.e., technical compatibility and digital integration requirements) influence stakeholder collaboration. Organizational factors (i.e., shared governance, communication protocols, and collaborative culture) determine the readiness and capacity for inter-organizational change. Environmental factors (i.e., policies, market demand, and regulatory support) shape the conditions for stakeholder collaboration. Thus, it is suitable for adopting the TOE framework as the theoretical foundation for exploring the factors affecting stakeholder collaboration in OSC projects.

2.3. Factors affecting stakeholder collaboration in OSC projects

Our study systematically retrieved and synthesized relevant literature on OSC, project management, and stakeholder collaboration via academic databases (e.g., Web of Science, Scopus, Google Scholar) to determine factors affecting stakeholder collaboration in OSC projects. It yielded an initial list of over 40 potentially relevant factors. Our study performed a two-stage screening process to refine the list of factors affecting stakeholder collaboration. First, our study merged conceptually overlapping factors according to similar contents and obtained 15 first-level factors. For example, "information sharing" and "information exchange" were consolidated into "communication". Second, our study conducted semi-structured interviews with eight experts to validate these factors and divided them into three dimensions of technology, organization, and environment according to their respective meanings. These eight experts are project managers and policymakers who have ten or more years of experience in OSC using Likert's 5-level scale (1 = Least important, 5 = Most important). Factors were retained with their value being greater than 4.0. The final nine factors are obtained (see Table 1).

2.3.1. Technical dimension

1) Task integration

Task integration in OSC projects encompasses the complexity of technology, the degree of standardization, and the interdependence between different tasks (Jang et al., 2022). OSC projects involve multiple entities, necessitating heightened specialization and collaboration among subprojects. For example, the production and delivery of prefabricated components to the construction site necessitate the comprehensive integration of procurement, planning, logistics, transportation, and other resources. Moreover, compared to traditional cast-in-place structures, modifications in OSC projects have a significant impact. Each design decision affects the manufacturing and installation of components (Zhang et al., 2020), highlighting the need for deeper design involvement. Precision in lifting, linking, welding, and grouting prefabricated components is critical. Modifications in ongoing tasks can trigger cascading effects on subsequent activities (Jiang et al., 2018a).

2.3.2. Organizational dimension

1) Communication

The frequency, content, and manner of communication play a critical role in the collaboration of OSC projects (Ma et al., 2023). Effective information exchange and communication establish collaborative channels among stake-

Table 1. Factors affecting stakeholder collaboration in OSC projects

Factors	TOE Dimension	Reference
Task integration	Technical	Jang et al. (2022), Jiang et al. (2018b), Zhang et al. (2020)
Communication	Organizational	Ma et al. (2023), Zhang et al. (2016, 2022)
Trust		Wong and Cheung (2004), Tang et al. (2019), Wang et al. (2016)
Benefit distribution		Chen et al. (2023), Teng et al. (2017), Zhai et al. (2017)
Risk-sharing		Lee et al. (2023), Luo et al. (2015), Wang et al. (2019b)
Contract		Ning (2017), Wu et al. (2018), Xue et al. (2022), Yan and Zhang (2020)
Mandatory-type policies	Environmental	Jiang et al. (2018b), Luo et al. (2021), Xue et al. (2021)
Incentive-based policies		Gao and Tian (2020), Wang et al. (2019a)
Industry competition		Ma et al. (2023), Tan et al. (2012), Xue et al. (2018), Zhou et al. (2024)

holders, supporting project decision-making (Zhang et al., 2022). In OSC projects, stakeholders often prioritize their interests over the overall interests of the industry chain, resulting in conflicts with others (Zhang et al., 2016). In this context, effective communication is essential for coordinating differences, fostering mutual trust, mitigating conflicting interests, and enhancing the implementation of stakeholder collaboration in OSC projects.

2) Trust

Trust is an informal governance mechanism that promotes collaboration in OSC projects, encompassing competence trust and institutional trust (Wong & Cheung, 2004). It means the trusting party relinquishes control and relies on the trusted party to pursue mutual interests. Empirical research by Wang et al. (2016) suggested that trust serves as a cost-effective safeguard for stakeholder collaboration compared to complex contracts. It nurtures a collaborative environment through social interactions, ensuring effective collaboration among stakeholders, viewed through informal relationship governance (Tang et al., 2019).

3) Benefit distribution

Benefit distribution involves allocating benefits to each stakeholder in OSC projects during construction phases. The objective is to motivate active collaboration by ensuring fair and systematic benefit allocation (Chen et al., 2023). Equitable benefit distribution is crucial for a stable partnership. However, Teng et al. (2017) argued that the current construction industry chain lacks scalability, leading stakeholders to prioritize maximizing their benefits in the project's early stages, heightening concerns throughout the cooperation process. Meanwhile, using a game theory approach, Zhai et al. (2017) concluded that unfair benefit distribution will diminish stakeholders' enthusiasm for continued collaboration.

4) Risk-sharing

Construction projects often involve various risks, and effective risk-sharing hinges on carefully identifying potential risks and distributing them among stakeholders (Wang et al., 2019b). In contrast to traditional engineering projects, OSC projects involve more stakeholders and complex interests (Hu et al., 2019), resulting in risks marked by volatility, uncertainty, and diversity (Luo et al., 2015). Lee et al. (2023) advocated that a rational risk-sharing model can serve as an incentive mechanism to enhance project governance standards, reduce transaction costs, and foster consistent collaboration within the project teams.

5) Contract

The contract is the formal governance framework and the fundamental governance mechanism for stakeholder collaboration (Xue et al., 2022). As a temporary organization, the OSC project team adopts a flexible structure established through contractual relationships with stakeholders. The contract explicitly outlines each stakeholder's rights and obligations in the OSC projects (Ning, 2017; Wu et al., 2018), creating a legally binding behavioral framework (Yan & Zhang, 2020), enabling stakeholders to navigate environmental uncertainty and deter opportunistic behaviors.

2.3.3. Environmental dimension

1) Mandatory-type policies

Mandatory-type policies are compulsory measures instituted by governmental or other authorities, possessing an enforceable nature (Luo et al., 2021). Although not directly involved, the government acts as a "visible hand" by formulating policies, overseeing compliance, and enhancing quality management to regulate OSC projects (Xue et al., 2021). Applicable mandatory-type policies can drive regional organizations or enterprises to establish alliances and implement OSC management models, guiding stakeholders to collaborate more efficiently (Jiang et al., 2018b).

2) Incentive-based policies

Incentive-based policies are key drivers of OSC projects, including the establishment of industrial bases, initiation of early pre-sale registrations, implementation of tax reduction and exemption protocols, provision of volume-based incentives, and offering fiscal subsidies (Wang et al., 2019a). Motivated by intrinsic interests, stakeholders are inclined to adopt proactive strategies, thereby promoting the integrated development of OSC projects (Gao & Tian, 2020). Additionally, stakeholders in the OSC projects also strengthen their core competencies and share project-related risks through collaboration.

3) Industry competition

Industry competition is a catalyst for fostering stakeholder collaboration in OSC projects (Zhou et al., 2024). This concept entails strategic interactions among businesses in the same industry to bolster competitiveness, encourage individual growth, develop new markets, and expand market reach (Tan et al., 2012). Industry competition drives stakeholders in OSC projects to actively seek ways to improve efficiency and reduce costs. As OSC remains an emerging sector with low market concentration and uneven capacity distribution, stakeholders across the industry chain must align their development efforts, build consensus on collaboration, share resources, technologies, and best practices, and establish strategic alliances to address dynamic market challenges (Ma et al., 2023; Xue et al., 2018).

2.3.4. Configuration model development

The above analysis reveals that each of the nine antecedents from technology, organization, and environment significantly influences stakeholder collaboration in OSC projects. However, from a configurational perspective, effective collaboration in OSC projects requires strong internal technical integration, robust interaction mechanisms, and substantial external support, which function synergistically through linkage and matching (Hu et al., 2019; Xue et al., 2022). Therefore, our study aims to explore the antecedent factors affecting stakeholder collaboration in OSC projects within the TOE framework and identify the configuration conditions fostering high stakeholder collaboration. The configuration model is shown in Figure 1.

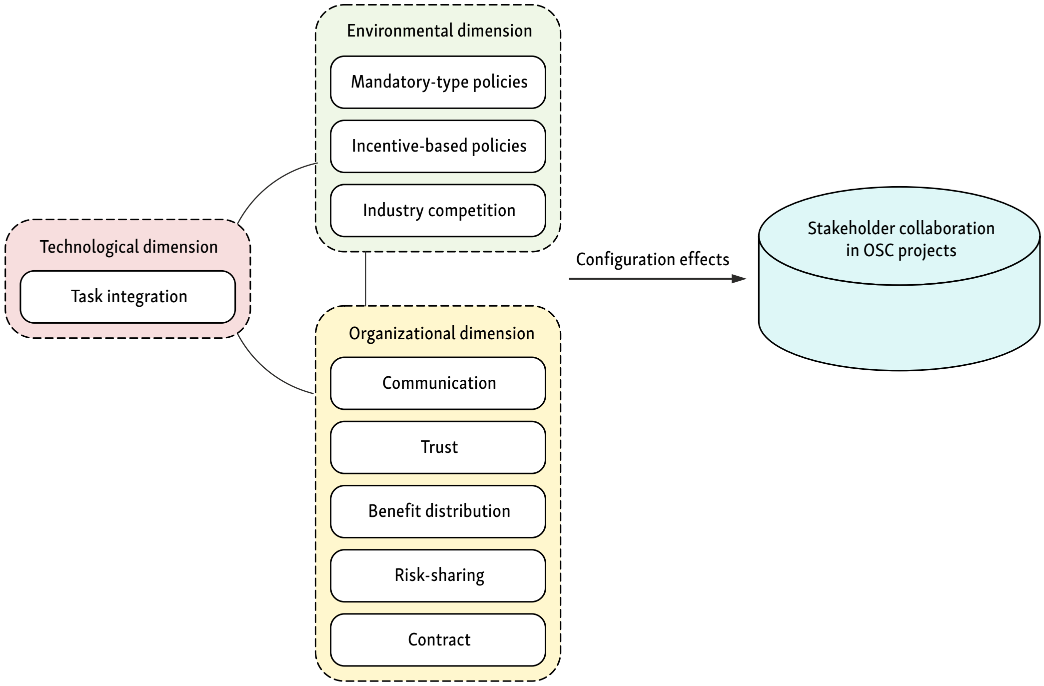

Figure 1. Configuration model

3. Research methodology

3.1. Analytical approach: fsQCA and NCA

OSC project development is nascent, and understanding associated collaborative behaviors appears indistinct (Li et al., 2024). Dul (2016b) suggested that integrating fuzzy set theory can effectively manage partial affiliation set relationships in fuzzy perception, enabling nuanced discernment of antecedent influences at different levels. Fuzzy set qualitative comparative analysis (fsQCA) and Necessary Condition Analysis (NCA) are used to examine the interaction effects of nine factors on stakeholder collaboration in OSC projects. It enables a comprehensive assessment of sufficient configurations and bottleneck conditions for achieving high stakeholder collaboration. First, fsQCA can ascertain the necessity of the conditions to attain the outcome (Dul, 2016b). Second, it uncovers different configurations leading to the same outcome by exploring the pathways (McKnight & Zietsma, 2018). Third, it combines the attributes of case study and qualitative analysis to explain the theoretical logic (Fiss, 2011; Wang et al., 2022). Fourth, it suits small- and medium-N studies, offering detailed analysis of complex causal recipes and configurations, rather than relying on large-sample statistical generalization (Ragin, 2009). Complementing fsQCA, NCA is employed to test for necessary conditions that can be used to identify the bottleneck factors by testing their necessity (Dul, 2016a).

3.2. Data collection

3.2.1. Procedure and participants

China's OSC projects have obtained attention, accounting for approximately 40% of global OSC projects. However, the market share remains low at 27% in China, which is less than one in other countries, which provides a relevant context for our study. Questionnaires are used to ensure the authenticity and validity, with demographic information (Table 2) and variable measurements (Table 3).

Questionnaires were distributed online and offline to collect data from December 1, 2022, to February 28, 2023. The respondents are mainly from the "2021 China's Top 100 Construction Enterprises" list published by the Chinese Construction Enterprises Management Association and the "Top 200 Sales List of Chinese Real Estate Enterprises in 2021" published by the China Real Estate Information (i.e., Vanke, Country Garden, and the China Construction Third Engineering Bureau Group, etc.) and the partners of these enterprises, including construction, design, and component production units, mitigating data analysis bias resulting from a singular enterprise or project. Additionally, questionnaires were distributed to the relevant government because the relevant policies can affect the stakeholder collaboration. To ensure data quality, our study implemented several measures during data collection. First, eight professionals with substantial work experience and advanced education were to scrutinize the questionnaire, ensuring its scientific and practical validity. Second, the questionnaire underwent a pilot phase to guarantee the credibility and validity of all variables. Finally, the concurrent distribution of paper and electronic questionnaires combined the convenience and speed of online methods with the depth of offline interactions, enhancing data comprehensiveness, quality, and response rates. A total of 131 questionnaires were collected, of which 103 were deemed valid after screening, resulting in a recovery rate of 78.63%.

Descriptive statistics were employed to analyze the personal information of the 103 validly obtained respondents, with the demographic characteristics of the respondents in Table 2. Over 97% of the respondents possess a bachelor's degree or higher, signifying their adeptness in comprehending the questionnaire's content owing to their academic prowess. The respondents hail from diverse sectors within the assembly building industry, guaranteeing a comprehensive survey scope. The respondents primarily occupy roles as general staff, grassroots or middle managers, and project managers within their enterprises, directly involved in managing OSC projects. Close to 70% of the respondents boast over three years of experience or engagement in the construction domain and over 70% involvement rate in OSC projects. The respondents' educational qualifications, professional tenure, and hierarchical roles significantly enhance the credibility of the gathered data.

3.2.2. Measurements

The measurement scales are developed as follows. First, our study systematically reviewed the existing literature and derived the initial set of measurement items based on established definitions and dimensions. Next, our study conducted semi-structured interviews with eight project managers experienced in OSC project management to supplement context-specific expressions and thereby enrich the initial item. Then, our study invited three scholars and practitioners with expertise in OSC project management to evaluate the items in terms of relevance, clarity, and representativeness. Through scoring and discussion, our study merged synonymous items, removed ambiguous or contextually inappropriate ones, and retained those with precise wording and comprehensive construct coverage for the pilot test. Fourth, a double back-translation procedure was combined with small-sample comprehensibility interviews. A bilingual research assistant translated the items forward, and then another translator, unfamiliar with the original scale, back-translated them. Discrepancies between the two versions were carefully compared and repeatedly revised. Finally, exploratory factor analysis was performed by eliminating items with low communalities or cross-loadings, and the measurement was obtained in Table 3.

3.3. Reliability and validity test

The Cronbach's α coefficients for each variable exceed the threshold of 0.7, indicating high internal consistency and reliability of the measurement scale. The Bartlett test results [Kaiser-Meyer-Olkin (KMO) = 0.809, Sig. = 0.000] confirm strong construct validity. Then, the convergent validity and discriminant validity of the scale were analyzed.

Table 2. Demographic characteristics of the respondents

Characteristics	Category	Number	Percentage
Age	<30	63	61.17%
	30–39	37	35.92%
	40–49	2	1.94%
	≥50	1	0.97%
Education attainment	Postgraduate	51	49.52%
	Undergraduate	49	47.57%
	Junior college and below	3	2.91%
Work unit	Construction unit	59	57.28%
	Design unit	7	6.8%
	Component production unit	13	12.6%
	Government sector	4	3.88%
	Research Institution/ Higher Education Institution	18	17.48%
	Others	2	1.9%
Position	Ordinary employee	44	42.72%
	Grassroots Manager	36	34.95%
	Middle manager	22	21.36%
	Top manager	1	0.97%
Time in/focused on the construction field	<3	31	30.1%
	3–4	28	27.18%
	5–9	33	32.04%
	≥10	11	10.68%
Whether engaged in OSC projects	Yes	73	70.87%
	No	30	29.13%

Table 3. Description of variables

Variables	Items	References
Task integration (TI)	Compared to traditional cast-in-place projects, OSC projects have more overall cross-work.	Xue et al. (2018), Jaillon and Poon (2010)
	Compared to traditional cast-in-place projects, OSC projects have higher overall complexity.	
	Compared to traditional cast-in-place projects, a change in the workload of one party is more likely to cause a shift in the workload of the cooperating party.	
	Compared to traditional cast-in-place projects, the work content of OSC projects has a higher demand for collaboration.	
	Compared to traditional cast-in-place projects, OSC projects are more likely to require collaborators to participate in decision-making.	
Communication (Com)	Our unit and our partners communicate frequently.	Lu et al. (2015), Griffith and Myers (2005)
	Our unit and partners have established good contacts to avoid possible misunderstandings.	
	Our unit and partners share information that may be useful to each other.	
	Our projects utilize efficient communication methods such as co-location and on-site meetings.	
Trust (Tr)	We believe our partners are capable of accomplishing the goals set forth.	Wong et al. (2008), Pinto et al. (2009)
	We believe our partners are competent in their work.	
	We believe our partners are specialized.	
	We believe our partners will keep their commitments throughout the project.	
	We believe our partners will not act in a way that is intentionally detrimental to the interests of others for personal gain.	
	We believe our partners will insist on fairness throughout the project.	
Benefit distribution (BD)	Benefits received by each stakeholder in OSC projects are directly proportional to the risks they take.	Zhang et al. (2016), Sarin and Mahajan (2001)
	Benefits received by stakeholders in the OSC project are directly proportional to the level of their resource input (degree of contribution).	
	The distribution of benefits among the stakeholders in OSC projects is fair and reasonable.	
	OSC projects implement incentives for each stakeholder based on target costs.	
	OSC projects implement penalties for each stakeholder based on target costs.	
Risk-sharing (RS)	Clear procedures and principles for dealing with risk factors that may be disputed in the future are set out.	Jin and Ling (2005), Julnes and Holzer (2001), Xia et al. (2022)
	Risks are allocated to the party that is best able to manage them.	
	In dealing with disputes or matters not agreed upon, due consideration is given to the reasonable interests of the parties concerned.	
	In dealing with disputes or matters not agreed upon, the responsibilities and powers of the parties involved are fully considered.	
Contract (Con)	The terms and methods of payment are specified in detail in the contract.	Xue et al. (2022), Ning (2018)
	The contract details the roles of both parties in accomplishing their respective tasks.	
	Specific requirements and standards during construction are detailed in the contract.	
	Contractual terms are highly legally binding on the parties involved in implementing the project.	
	The contract establishes severe penalties for failure to perform.	
	Extra-contractual matters or work requiring a contract to be signed before work is started.	
	Contract details the manner or means by which disputes/disputes are to be resolved.	
Mandatory-type policies (MTP)	Current standards and codes for OSC projects are well established.	Hsu et al. (2013), Wu et al. (2012)
	The government where the project is located has introduced a land grant policy to develop OSC projects.	
	Government-funded projects (e.g., subsidized housing, affordable housing, talent housing) are required to adopt the OSC model.	
	Where the project is located, the government has set a minimum assembly rate for developing OSC projects.	
	The government will continuously monitor the OSC projects to ensure that the technical standards and specifications are implemented.	
Incentive-based policies (IBP)	The government offers financial subsidies for OSC projects.	Shazmin et al. (2016), Mao et al. (2015)
	The government offers tax policy incentives for OSC projects.	
	The government offers interest relief concessions for OSC projects.	
	The government supports OSC projects with plot ratio incentives.	
	The government provides a pre-sale support policy for OSC projects.	

End of Table 3

Variables	Items	References
Industry competition (IC)	Our competitors are developing OSC projects.	Shalley and Oldham (1997), Razkenari et al. (2020)
	Our upstream and downstream companies are developing OSC projects.	
	Our unit can capture a significant market share by developing assembly technology, design, and construction.	
	Our unit can maintain a competitive edge in the marketplace by developing OSC projects.	
	Our unit can establish a good market image by developing OSC projects.	
Stakeholder collaboration (SC)	During the project's construction, we can clearly understand the boundaries of our tasks.	Hoegl and Weinkauf (2005), Marks et al. (2001), Montoya et al. (2011)
	We can quickly coordinate and combine resources when work content changes.	
	In disagreements during construction, the project stakeholders can still perform their respective tasks and responsibilities quickly.	
	We will adjust our progress according to the task completion of other partners in due time.	
	The project partners can make critical decisions in project construction by mutual agreement.	
	We can quickly obtain help from our partners when difficulties are encountered during the project's construction.	

The minimum factor loading is 0.544, the minimum AVE is 0.505 (both exceeding the threshold of 0.5), and the minimum CR is 0.800 (above the criterion of 0.7), demonstrating good convergent validity (Table 4). Furthermore, the square roots of the AVEs for all constructs are greater than their corresponding inter-construct correlation coefficients, confirming the scale's discriminant validity (Table 5).

Reliability and validity tests (Cronbach's α, KMO, AVE, and CR) are usually applied to confirm the questionnaire's soundness. A sample size of 103 (belonging to medium-N research studies) is adequate for fsQCA and acceptable for foundational assessments. The observed reliability and validity metrics confirm that the collected data meet the quality requirements for subsequent configurational analysis.

Table 4. Construct reliability and convergent validity

Variables	Measure items	Cronbach'sα coefficients	Estimate	CR	AVE
TI	TI1	0.827	0.544	0.835	0.507
	TI2		0.631		
	TI3		0.769		
	TI4		0.794		
	TI5		0.788		
Com	Com1	0.864	0.786	0.868	0.624
	Com2		0.891		
	Com3		0.796		
	Com4		0.670		
Tr	Tr1	0.909	0.853	0.912	0.635
	Tr2		0.865		
	Tr3		0.807		
	Tr4		0.761		
	Tr5		0.746		
	Tr6		0.739		
BD	BD1	0.818	0.659	0.842	0.516
	BD2		0.739		
	BD3		0.720		
	BD4		0.752		
	BD5		0.719		
RS	RS1	0.708	0.660	0.800	0.505
	RS2		0.565		
	RS3		0.762		
	RS4		0.828		

End of Table 4

Variables	Measure items	Cronbach'sα coefficients	Estimate	CR	AVE
Con	Con1	0.875	0.745	0.886	0.528
	Con2		0.760		
	Con3		0.757		
	Con4		0.741		
	Con5		0.655		
	Con6		0.616		
	Con7		0.795		
MTP	MTP1	0.899	0.853	0.906	0.661
	MTP2		0.869		
	MTP3		0.871		
	MTP4		0.711		
	MTP5		0.746		
IBP	IBP1	0.853	0.580	0.869	0.575
	IBP2		0.768		
	IBP3		0.802		
	IBP4		0.772		
	IBP5		0.841		
IC	IC1	0.882	0.710	0.876	0.587
	IC2		0.722		
	IC3		0.830		
	IC4		0.778		
	IC5		0.783		
SC	SC1	0.890	0.743	0.885	0.562
	SC2		0.781		
	SC3		0.743		
	SC4		0.732		
	SC5		0.743		
	SC6		0.753		

Table 5. Discriminant validity

Variables	TI	Com	Tr	BD	RS	Con	MTP	IBP	IC	SC
TI	0.507									
Com	0.216	0.624								
Tr	0.249	0.661	0.635							
BD	0.074	0.466	0.55	0.516						
RS	0.199	0.575	0.532	0.649	0.505					
Con	0.198	0.661	0.663	0.549	0.491	0.528				
MTP	0.207	0.457	0.48	0.414	0.365	0.521	0.661			
IBP	0.232	0.617	0.493	0.537	0.472	0.602	0.562	0.575		
IC	0.073	0.473	0.499	0.466	0.402	0.558	0.4	0.59	0.587	
SC	0.222	0.732	0.662	0.575	0.604	0.653	0.458	0.739	0.663	0.562
The square root of AVE	0.712	0.790	0.797	0.718	0.711	0.727	0.813	0.758	0.766	0.750

3.4. Calibration

In fsQCA analysis, the independent and outcome variables need to be calibrated, which refers to assigning pooled affiliation scores to the cases. Referring to the qualitative criteria of the existing studies, in our study, the 95% quartile, 50% quartile, and 5% quartile of the effect and condition variables were used as "full membership," "crossover point" and "full non-membership" anchors (Basurto & Speer, 2012; Wagemann et al., 2016). The data after calibration are presented in Table 6.

Table 6. Variable calibration anchors

Variables	Calibration		
	Full membership	Crossover point	Full non-membership
TI	4.6	3.6	2.4
Com	4.63	3.62	2.6
Tr	4.27	3.4	2.4
BD	4.17	3.25	2.62
RS	4.17	3.4	2.4
Con	5	3.67	2.44
MTP	4.93	3.75	2.3
IBP	4.8	3.4	2.4
IC	5	3.8	2.4
SC	5	3.6	2.3

4. Results

4.1. Necessary conditions analysis

Necessity conditions analysis was conducted by using fsQCA 3.0 software. The results show that the consistency of each variable is good fitness due to the value being less than 0.90 (see Table 7). It means that none of the variables can be considered necessary conditions for the stakeholder collaboration achievement in the OSC projects. Therefore, it is essential to conduct a configuration analysis to identify the specific configurational conditions required for achieving high stakeholder collaboration.

NCA is used to identify necessary antecedents and determine the extent to which an antecedent functions as a bottleneck for the outcome (Dul, 2016a). NCA was analyzed using Concave Envelope (CE), which is suitable for binary or discrete variables with limited levels, and Concave Regression (CR), which is suitable for discrete or continuous variables with multiple levels. The results of NCA are shown in Table 8.

A condition can be viewed as the necessary conditions when it meets two standard (Dul, 2016b; Dul et al., 2020; Vis & Dul, 2018). (1) The effect size (d) is exceeded 0.1 (i.e., $0.1 < d \leq 0.3$ indicates low influence; $0.3 < d \leq 0.5$ indicates high influence). (2) Results are significant in Monte Carlo permutation tests ($p < 0.05$). As Table 8 shows, the results of each variable are significant ($p < 0.05$), and the effect size ($d < 0.1$) is low, meaning these factors are not the necessary condition for stakeholder collaboration in OSC projects.

Then, a bottleneck-level analysis was conducted to reveal the detailed descriptions of the necessary bottleneck levels for the given outcome (Dul, 2016b). Table 9 presents the bottleneck degree of variables, indicating the percentile levels of conditions required to reach the given percentile of stakeholder collaboration. NN means that a condition is not a necessary condition for stakeholder collaboration in OSC projects. For instance, to achieve 80% stakeholder collaboration, communication should be at least 36.3%, trust should be at least 38.4%, benefit distribution should be at least 25.5%, risk-sharing should be at least10.8%, and the contract should be at least 40.6%. Conversely, to achieve 50% stakeholder collaboration, only the trust level needs to reach 2.9% and the contract level needs to reach 10.5%; other conditions are not necessary for stakeholder collaboration.

Table 7. Analysis of necessity for stakeholder collaboration

Independent Variable	Outcome Variable			
	High SC		Poor SC	
	Consistency	Coverage	Consistency	Coverage
TI	0.694	0.634	0.638	0.643
~TI	0.609	0.604	0.637	0.697
Com	0.779	0.789	0.520	0.580
~Com	0.585	0.525	0.811	0.802
Tr	0.847	0.786	0.577	0.591
~Tr	0.559	0.545	0.791	0.851
BD	0.761	0.743	0.533	0.574
~BD	0.563	0.522	0.762	0.779
RS	0.719	0.749	0.507	0.583
~RS	0.600	0.525	0.782	0.754
Con	0.808	0.745	0.562	0.572
~Con	0.535	0.526	0.749	0.812
MTP	0.866	0.801	0.539	0.550
~MTP	0.513	0.502	0.805	0.868
IBP	0.796	0.727	0.593	0.597
~IBP	0.559	0.555	0.728	0.797
IC	0.787	0.807	0.527	0.596
~IC	0.606	0.538	0.829	0.811

Notes: "~" means "the absence of". For example, ~TI = absence of high task integration.

Table 8. Results of necessary condition analysis

Variables	Methods	Accuracy	Ceiling Zone	Scope	Effect Size (d)	P-value (p)
TI	CR	100%	0.004	0.99	0.004	0.878
	CE	100%	0.010	0.99	0.010	0.811
Com	CR	100%	0.075	0.99	0.076	0.215
	CE	100%	0.069	0.99	0.070	0.196
Tr	CR	100%	0.077	0.99	0.078	0.095
	CE	100%	0.082	0.99	0.083	0.086
BD	CR	100%	0.068	0.99	0.069	0.317
	CE	100%	0.055	0.99	0.056	0.368
RS	CR	100%	0.042	0.99	0.042	0.305
	CE	100%	0.051	0.99	0.052	0.412
Con	CR	100%	0.086	0.98	0.088	0.036
	CE	100%	0.075	0.98	0.077	0.062
MTP	CR	100%	0.036	0.98	0.037	0.423
	CE	100%	0.039	0.98	0.040	0.416
IBP	CR	100%	0.011	0.99	0.011	0.773
	CE	100%	0.010	0.99	0.010	0.804
IC	CR	100%	0.022	0.98	0.022	0.601
	CE	100%	0.029	0.98	0.030	0.498

Notes: CR is used to measure the necessity of the conditions. CE is used to compare the robustness of the results. P-value is obtained by using the permutation test with 10,000 redraws in the NCA method.

Table 9. Bottleneck-level (%) analysis of necessary conditions

SC	TI	Com	Tr	BD	RS	Con	MTP	IBP	IC
0	NN	NN	NN	NN	NN	NN	NN	NN	NN
10	NN	NN	NN	NN	NN	NN	NN	NN	NN
20	NN	NN	NN	NN	NN	NN	NN	NN	NN
30	NN	NN	NN	NN	NN	NN	NN	NN	NN
40	NN	NN	NN	NN	NN	0.5	NN	NN	NN
50	NN	NN	2.9	NN	NN	10.5	NN	NN	NN
60	NN	7.3	14.7	NN	3.2	20.6	NN	NN	NN
70	NN	21.8	26.5	9.0	7.0	30.6	NN	NN	NN
80	NN	36.3	38.4	25.5	10.8	40.6	NN	NN	NN
90	NN	50.9	50.2	41.9	14.6	50.7	25.8	10.1	NN
100	55.7	65.4	62	58.4	18.4	60.7	81.4	20.8	77.4

Notes: "NN" means not necessary.

4.2. Configuration conditions of stakeholder collaboration in OSC projects

The Quine-McCluskey was used to analyze sufficient conditions embedded in the fsQCA 3.0 software. It helps simplify the data's complexities, providing a concise outcome. Our study selects 0.70 as the threshold to evaluate consistency (Fiss, 2011; Ragin, 2006), and the threshold is one for the coverage.

Eight configurational solutions are obtained to achieve the high stakeholder collaboration in OSC projects (see Table 10), with solution consistency being 0.916 and solution coverage being 0.669. Our study classified eight configurational solutions into three categories based on their core conditions: S1 being environment-driven organizational configuration with S1a, S1b, S1c, and S1d; S2 as technology-organizational configuration with S2a and S2b, and S3 as organizational-driven environment configuration with S3a and S3b.

Solution 1 (S1) is an environment-driven organizational configuration with core conditions as high trust (O), mandatory-type policies (E), and industry competition (E). The raw coverage values of S1a to S1d are 0.288, 0.330, 0.423, and 0.263, and the consistency values all exceed 0.9. These four solutions suggest that the interaction between organizational trust, mandatory-type policies, and industry competition can promote stakeholder collaboration in OSC projects.

Solution 2 (S2) is a technology-organizational configuration with core conditions as high task integration (T), benefit distribution (O), and contract (O), alongside the non-high incentive-based policies. The raw coverage values of S2a to S2b are 0.407 and 0.269, and the consistency values all exceed 0.9. It suggests that the interaction of technological factors with robust organizational practices, such as high task integration, equitable benefit distribution, and explicit contractual agreements, is sufficient for achieving stakeholder collaboration, even in environments without strong incentive-based policies.

Solution 3 (S3) is an organizational driven environment configuration with core conditions of high benefit distribution (O), trust (O), and mandatory-type policies (E). The raw coverage of S3a to S3b is 0.290 and 0.433, and the consistency values all exceed 0.9. It suggests that with mandatory-type policies, stakeholder collaboration can be achieved if reasonable benefit distribution and good team trust exist.

5. Discussion and implications

5.1. Discussion

For S1, the configuration of heightened organizational trust (O) with environmental pressures, including mandatory policies (E) and industry competition (E), enhances stakeholder collaboration in OSC projects. Heightened trust facilitates consensus building, coordination, and effective collaboration to achieve shared goals. The effect intensifies with strict mandatory policies and competitive industries. Mandatory policies enhance trust and collaboration by regulating exclusive land grants, refining standard specifications and improving governmental oversight. Industry competition incentivizes stakeholders to collaborate for mutual benefits, creating a win-win scenario that enhances efficiency and competitiveness. Also, incentive policies are viewed as the peripheral condition in S1a to S1d, which implies that incentives and mandatory-based policies promote stakeholder collaboration in OSC projects. Previous studies highlighted practical hurdles for adopting measures similar to the S1 pathway, including fragmented regulatory landscapes, outdated building codes, and internal organizational rigidities that impede agility and inter-organizational trust (Gan et al., 2018; Lei et al., 2017; Zhang et al., 2024). However, our findings highlight the significance of combining organizational trust, aligned policies, and market forces to overcome these challenges. Although environmental demands, such as sustainability goals or labor shortages, create conflicting priorities, the S1 configuration offers a view for integrating diverse pressures into collaborative outcomes. The findings suggest that stakeholders involved in OSC projects can adopt a multifaceted approach to address S1. (1) Fostering team trust is essential for stakeholder collaboration in OSC projects, which can be achieved through regular team-building activities and shared goal-setting. (2) Mandatory and incentive-based policies mandatory-type and incentive-based policies can be implemented to achieve stakeholder collaboration. Governments can ensure project quality and safety through explicit norms and standards, alongside motivating participation in OSC projects via incentives like tax concessions and financial support. (3) Fostering industry competition is crucial for trust and collaboration. Establishing a competitive market environment encourages healthy competition between different stakeholders and facilitates resource, technology, and experience-sharing through industry alliances, which can foster beneficial stakeholder collaboration.

For S2, the configuration of high task integration (T) with robust organizational governance mechanisms, including benefit distribution (O) and contract governance (O), suffices to achieve high stakeholder collaboration in non-high incentive policy environments. High task integra-

Table 10. Configurational conditions for the presence of high stakeholder collaboration

Configuration	Solution 1 (S1)				Solution 2 (S2)		Solution 3 (S3)	
	S1a	S1b	S1c	S1d	S2a	S2b	S3a	S3b
TI	⨂	⨂	•	•	●	●	⨂	•
Com	⨂	•	•	⨂		•	•	•
Tr	●	●	●	●	⊗	•	●	●
BD	•	•		⊗	●	●	●	●
RS	⨂		•	⊗	•	•	•	•
Con		•	•	•	●	●	•	•
MTP	●	●	●	●	⊗	⊗	●	●
IBP	•	•	•	•	⨂	⨂	⊗	•
IC	●	●	●	●	⊗			
Raw coverage	0.288	0.330	0.423	0.263	0.407	0.269	0.290	0.433
Unique coverage	0.049	0.024	0.020	0.019	0.006	0.013	0.028	0.032
Consistency	0.938	0.907	0.928	0.926	0.930	0.928	0.942	0.933
Solution coverage	0.669							
Solution consistency	0.916							

Notes: ● – core condition present; ⨂ – core condition absent; • – peripheral condition present; ⊗ – peripheral condition absent.

tion implies interdependence among stakeholders' tasks and activities, making stakeholder collaboration inevitable. Reasonable benefit distribution entails stakeholders receiving excellent returns from the project. Shared distribution of benefits motivates all stakeholders to foster active participation. Explicit terms indicate well-defined contracts and regulations in project collaboration, standardizing stakeholders' responsibilities and rights, and mitigating uncertainty and potential conflicts. Transparent contracts foster trust among stakeholders, establishing a predictable collaboration mechanism. Non-high incentive-based policies instead enhance stakeholder collaboration in OSC projects. It suggests that a long-term collaboration is emphasized, where the intrinsic strengths of technological integration and sound organizational practices are paramount. Such a configuration indicates that policies should encourage organizations to prioritize stable synergistic relationships over rewards and penalties based solely on immediacy. Although previous studies suggest that similar pathways face resistance, such as platform incompatibility and inadequate professional training in digital tools (Mao et al., 2015; Shen et al., 2024; Zhai et al., 2014), our findings show that prioritizing task interdependence, equitable benefit distribution, and clear contracts creates a strong collaboration environment rather than short-term incentives. It mitigates technological adoption and organizational capacity, promoting sustainable collaboration even when new technologies overwhelm organizations and dilute benefits. In contrast to S1, S2 advocates for prioritizing long-term collaboration among stakeholders, which focuses less on immediate policy incentives and more on establishing stable and legally binding internal synergies. For example, OSC projects can clearly define each stakeholder's roles and responsibilities, align project objectives closely with the core interests of each participant, and ensure equitable returns via flexible contractual arrangements. By implementing a robust internal synergy mechanism, stakeholder collaboration can be attained without external incentive-based policies.

For S3, the configuration of supportive environmental policies (E) and strong organizational relational governance, including benefit distribution (O) and trust (O) is sufficient for stakeholder collaboration. Reasonable benefit distribution ensures stakeholders anticipate significant project returns, incentivizing active collaboration driven by the potential for substantial economic and strategic gains. High trust indicates the establishment of robust trust relationships among stakeholders, enabling them to believe in each other's capacity to fulfill commitments, collaborate in problem-solving, and collectively pursue project objectives. Trust presence minimizes collaboration barriers, expedites information exchange, and enhances efficiency. Other organizational factors (i.e., communication, risk-sharing, and contract) are the peripheral conditions in S3a to S3b, which underscore that good organizational relationships form the foundation for stakeholder collaboration in OSC projects. Incorporating appropriate mandatory-type policies can ensure stakeholders fulfill their collaborative responsibilities, mitigating uncertainty and risk. While S3 resembles S1 in the importance of mandatory policies, S3 emphasizes the proactive role of organizational relational governance in leveraging environmental conditions. It indicates that organizations with a well-developed governance mechanism can collaborate well on appropriate external policy directions. Although previous studies suggest that similar pathways face resistance, such as regulatory inertia from governing bodies and the significant investment required for uncertain policy advocacy (Luo et al., 2015; Pan et al., 2008; Wuni & Shen, 2020), our findings show that robust governance combined with strategic policy engagement enhances stakeholder collaboration. Aligning internal strengths with external policy advocacy helps overcome common barriers. Therefore, OSC project managers should prioritize establishing relational governance by defining roles, cooperation rules, and benefit distribution mechanisms. This approach regulates team members' conduct, enhances trust, and fosters collaboration. Stakeholders can also align with government policies, utilizing policy guidance to improve the stakeholder collaboration level in OSC projects.

5.2. Theoretical and practical implications

5.2.1. Theoretical implications

Our study enriches the literature on the antecedent factors shaping stakeholder collaboration in OSC projects. Previous studies focused on isolated impacts of single influencing factors through empowerment (Mao et al., 2015; Xue et al., 2018), overlooking exploring the theoretical framework of these antecedents to achieve stakeholder collaboration. By employing the fsQCA-NCA approach, our study systematically uncovers nine pivotal factors that condition stakeholder collaboration outcomes in OSC projects. The results confirm the absence of single bottleneck factors, underscoring the inadequacy of single-factor explanations and reinforcing the need for a configurational perspective.

Our study elucidates the equivalence and substitution mechanisms among pivotal factors from the configuration perspective. Previous studies have utilized regression or contingency perspective analysis (Al-Aidrous et al., 2023; Alazzaz & Whyte, 2015; Dou et al., 2019; Liu et al., 2022), overlooking their interdependence. Our study focuses on the configuration of antecedent factors, demonstrating that multiple factors interact with each other to achieve high stakeholder collaboration in OSC projects via configurational effects. It indicates the practical approach is not singular but involves substitution relationships. Our study enriches TOE by testing the interaction between factors of the technological, organizational, and environmental dimensions.

5.2.2. Practical implications

Through S1 to S3, our study provides four practical and managerial insights into stakeholder collaboration in OSC projects for policymakers, project managers, and stakeholders, as follows:

(1) Enhance the project management model and emphasize enduring collaboration among stakeholders. As a pivotal strategy for achieving construction industrialization, integrated management is a crucial aspect of OSC projects. The EPC integration model should specifically cater to OSC projects. General contracting construction businesses should assume leadership roles and collaborate with upstream and downstream entities through strategic agreements to forge an industrial alliance. This approach will foster a robust and symbiotic relationship, mitigate costs through a highly integrated organizational framework, and collaboratively explore unified standards to achieve stakeholder collaboration in OSC projects.

(2) An equitable benefit distribution mechanism for stakeholders must be devised to achieve collaboration. A rational benefit distribution mechanism can incentivize stakeholders to share project benefits, enhancing sustainability. Stakeholders in OSC projects should contemplate adopting a risk-sharing and benefit-sharing mechanism to align project benefits with their contributions. Concurrently, an information-sharing mechanism should ensure all parties are informed and engaged, preventing collaboration bottlenecks due to uneven benefit distribution.

(3) A complementary contract and relational governance framework should be developed, and the resilience, rigidity, and flexibility of collaboration should be balanced for improving stakeholder collaboration in OSC projects. An efficient contract management system is crucial to clarify stakeholders' roles and obligations. The contract should comprehensively outline the project's execution plan, quality standards, safety requirements, and other relevant facets. Simultaneously, it must also integrate some flexible factors (i.e., communication, trust, and others) to foster a mutual "support mechanism" for contract and relationship governance, promoting the spirit of trust and collaboration among stakeholders, thereby enhancing stakeholder collaboration in OSC projects.

(4) Governments should implement mandatory-type and incentive-based policies concurrently. Serving as the "visible hand", the government must adeptly manage its scope of oversight. Diverse incentives should attract construction enterprises to OSC projects during the initial development phase. However, incentive-based policies have not significantly impacted, primarily due to their focus on real estate enterprises. Subsequent policy evolution should broaden recipient groups to ignite collaborative zeal among general contracting enterprises, prefabricated component manufacturers, and others. Policy oversight must be strengthened to ensure adherence to technical standards and specifications in OSC projects, including assembly rates, project quality, safety, and other stipulations. Meanwhile, governmental intervention must be reasonable and aligned with market development principles to sustain the OSC project's market vitality and promote healthy industry competition.

6. Conclusions

Technology-Organization-Environment factors significantly affect OSC projects' stakeholder collaboration, but their configuration effects on stakeholder collaboration remain unclear. Utilizing 103 valid questionnaires, our study employs NCA to test for necessary conditions. The result shows that a single factor alone does not lead to stakeholder collaboration. Then, our study employs fsQCA to explore three configurational paths to achieve high stakeholder collaboration in OSC projects: environment-driven organizational configuration, technology-organizational configuration, and organizational-driven environment configuration. These represent "different paths to the same destination" when promoting stakeholder collaboration in OSC projects. Finally, configuration conditions were found to have asymmetric causality for the presence or absence of high stakeholder collaboration in OSC projects. Our study further expands the TOE framework's application scope at the technical application level. It provides practical decision-making guidance for policymakers, project managers, and stakeholders.

Despite our best efforts, our study has several limitations. First, it uses the TOE framework to identify nine key factors influencing stakeholder collaboration in the early stages of OSC project development. However, as the OSC projects' industry chain advances, it is essential to consider other pivotal factors, such as initial costs and the talent training system. Future studies can explore these factors more comprehensively. Second, due to data collection limitations, our study gathers data from various units within the Chinese OSC industry. Future studies can conduct cross-cultural comparative research by collecting data from multiple countries or regions.

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