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Fostering Knowledge Collaboration in Construction Projects: The Role of BIM Application

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Abstract: Knowledge collaboration is beneficial for project parties to assess valuable knowledge resources from others in order to enhance their competitive advantages. However, knowledge collaboration is hampered by the special project environment and temporary structure of construction projects. Based on relational contract theory, this study employs trust and relational norms as the two relational governance mechanisms for improving knowledge collaboration. Next, this study explores the effect of relational governance mechanisms on knowledge collaboration and the moderating role of the building information modelling (BIM) application level. We collected data from 166 responses in construction projects. Our results reveal that relational norms significantly impact knowledge collaboration, which is contrary to the effect of trust. Furthermore, the BIM application level has an interactive effect with relational norms, which improves knowledge collaboration. These findings reveal that the level of BIM application significantly affects the effectiveness of relational governance mechanisms. This study suggests that project managers should help project parties to develop BIM responsibilities in order to facilitate collaborative performance.

Keywords: BIM application; knowledge collaboration; relational governance; construction projects

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1. Introduction

The whole process of construction projects suffers from fragmentation, from decision making and implementation through to operation. This is mainly because each project party focuses on completing their project tasks as defined by contracts and pursues the maximization of their interests, resulting in problems such as safety accidents, schedule delays, cost overruns, and contract disputes [1,2]. Despite the innovation of construction technologies and modes, the above problems have not yet been resolved. With the ongoing trend towards knowledge management for construction projects, knowledge collaboration becomes an effective collaboration approach that can elevate the efficiency of construction project management to add value to construction projects [3]. For example, the whole-process engineering consulting proposed in China in 2017 requires professionals to integrate fragmented knowledge by knowledge collaboration in the consulting process, to provide intellectual services for the whole project life cycle, ultimately adding value to the construction projects. Moreover, a new integrated project delivery mode requires project participants from different organizations with different professional backgrounds to get involved in a project early on and to integrate talent and differentiated knowledge to enhance the project's performance [4]. These collaborative processes are strongly associated with the effectiveness of knowledge integration and sharing [5]. Therefore, collaboration among project parties gradually transforms from knowledge cooperation to resource-based cooperation, due to the integration and specialization of construction projects [6].

Knowledge collaboration as a critical strategy can improve knowledge management performance and competitive advantages for construction project organizations [7]. It helps to overcome the barriers of construction project complexity, environment unpredictability, limited resource, and high cost, since effective knowledge collaboration helps project parties to assess valuable knowledge resources from other parties in order to accomplish project tasks. Chiocchio et al. (2011) argued that project parties' knowledge, timely devoted to the collaborative processes, could provide opportunities for greatly enhancing project performance [8]. However, knowledge collaboration is challenging in practice because of the special project environment (e.g., complex mechanical equipment, personal quality, and technical solutions), temporary cross-organizational structure with short cooperation duration, low-level trust, and maximization of personal interests [9]. Moreover, because knowledge, especially tacit knowledge, is possessed by individuals and manifested by heterogeneity due to the differentiated backgrounds of project parties, it is difficult to develop cooperation-based knowledge exchanges in a short time [10]. This will hinder knowledge cooperation behavior and the willingness of project parties, leading knowledge collaboration into a dilemma.

Relevant research has been performed to facilitate knowledge collaboration in construction projects. For instance, Zhang et al. (2018) demonstrated that formal contractual governance is a vital mechanism for stimulating cooperative efforts to conduct project practices, resulting in value and performance for the parties [11]. Formal governance provides binding promises for specific actions to increase value creation [12]. Nevertheless, the governance of knowledge collaboration and exchanges between inter-organizational project parties in construction projects involves more than the formal governance mechanisms because the exchange hazards, such as free-riding, distrustful relationships, and opportunism, are ever-present under the protection of formal contracts [13]. Additionally, knowledge collaboration is embedded in social relationships and requires inter-organizational social exchanges [14]. Therefore, relational governance that complements formal mechanisms can reduce the risk of exchange hazards protected by contracts and, ultimately, foster knowledge collaboration.

Based on relational contract theory, relational governance adopts trust and relational norms to influence social exchanges among temporary social relationships to promote collaboration [15,16]. Relational governance could enhance the probability that relational norms and trust inhibit the exchange hazards [12]. Relational norms involve the shared informal principles that declare the degree of appropriate and permitted behaviors, which could impede the project parties' opportunism in knowledge practices [10]. Moreover, the trust mechanism helps project parties to believe in each other's knowledge that is devoted to project goals and successes [17]. Therefore, trust and relational norms significantly foster knowledge collaboration in construction projects.

Although relational governance encourages project parties to devote knowledge to problem resolving and decision making, guidelines are still needed to catalyze the collaborative process. Oraee et al. (2017) considered that collaboration is considerably related to effective information exchanges and communications among each party [18]. A building information model (BIM) can improve information and knowledge exchanges among project parties through a collaborative process [19]. BIM integrates all knowledge and information associated with the project plan, design, construction, and operation. Such an information platform enables project parties to share and access knowledge and information transparently to solve the conflicts of plan, design, and project control that support the informal processes to foster collaboration [20,21]. It is a core repository that restores project data and helps parties to collaboratively conduct BIM-enabled project tasks (e.g., energy simulation, conflict detection, site analysis, design optimization, and cost estimation) [22]. Marinho et al. (2021) considered that the BIM application enhances collaborative efficiency by decreasing errors, strengthening trust, and reducing information asymmetry [23]. As a social and technical tool, BIM integrates technical and social components. It fosters knowledge collaboration among various parties in the project cycle and ultimately enhances project efficiency and productivity [23–25]. Therefore, the challenge becomes improving the level of BIM application in construction projects. This study aims to investigate the impact of relational governance mechanisms (i.e., trust mechanism and relational norms mechanism) on knowledge collaboration among the key parties in construction projects. In particular, we will endeavor to answer the two main questions as follows:

RQ1. Does the implementation of relational governance mechanisms foster knowledge collaboration in construction projects?

RQ2. How can the BIM application regulate the impact of the two mechanisms on knowledge collaboration in construction projects?

Next, this study conducted a questionnaire-based empirical survey to address these questions. The research results can offer practical implications for project managers to effectively foster knowledge collaboration in construction projects.

2. Theoretical Background and Hypotheses Development

2.1. Knowledge Collaboration in Construction Projects

Knowledge management always suffers from low efficiency and fragmentation in the complicated environment of construction projects [1]. In such a complex environment, each project party focuses on project tasks specified in contracts and pursues maximization of their interests, leading to problems such as safety accidents, schedule delays, cost overruns, and contract disputes [26]. It aims to integrate and collaborate the multi-disciplinary knowledge of project parties to manage uncertainty and resolve these problems. Relevant studies propose that knowledge collaboration is a valuable collaborative approach that helps to elevate project management efficiency and ultimately adds value to construction projects [3]. For instance, Zhang and He (2016) argue that integrated project delivery expects project parties' early participation in projects and positive integration of knowledge to optimize knowledge collaboration [27]. Furthermore, Oraee et al. (2019) consider that BIM relies on the collaborative knowledge network to ensure the effective diffusion of knowledge among network nodes [28]. Therefore, cooperation between project parties has transformed from resource-based cooperation to knowledge-based collaboration because of the development of delivery methods and information technology.

According to Karlenzig and Patrick (2002), knowledge collaboration is an important organizational strategy and can dynamically integrate different knowledge resources to enhance business performance [29]. Knowledge collaboration involves accumulating, sharing, transferring, transforming, and co-creating knowledge [30]. Previous studies have confirmed that construction project parties obtain valuable knowledge resources from other parties to maximize project management performance [31]. However, due to the temporary and cross-organizational project structure, it is not easy to develop a trust relationship in the short term [32]. Moreover, because of the inherent characteristics of knowledge (e.g., diversity, heterogeneity, and tacitness), project parties hesitate to share their valuable and tacit knowledge and experience with others, which impedes knowledge collaboration. Accordingly, it is necessary to explore how to foster knowledge collaboration in construction projects. This study adopts a relational governance approach to guide, regulate and motivate the knowledge behavior of project parties for higher-level knowledge collaboration.

2.2. Relational Governance and Knowledge Collaboration

Since formal contractual governance, based on control and enforced by authority and ownership, is defective due to the lack of crucial social elements, dealing with unforeseen events, such as social issues impeding knowledge collaboration, may be inefficient [33]. In contrast, as an informal governance approach, relational governance manifested by social elements can fill the gap. Relational governance has attracted sustained attention in the knowledge management of construction projects due to its features displayed by the expectations of high-level collaboration, trust, and social sanctions [34]. Based on relational contract theory, relational governance tries to specify the fundamental goals and relational principles instead of declaring the transaction terms [35]. It focuses on long-term trust and relational norms that can reduce transaction costs, increase transactive value, and develop more acceptable and flexible transaction relationships among project parties [36]. Therefore, relational governance aims to enhance social interactions rather than give each project party formal control or authority.

As a form of relational governance mechanism, relational norms declare permitted behavior and thus act as a protective mechanism that resists abnormal behavior [37]. As a crucial mechanism of relational governance, relational norms are developed with the bilateral social exchange of project partners who understand and agree with each other's expectations [38]. Relational norms involve flexibility, solidarity, and information sharing. Therein, flexibility helps project parties to flexibly adjust contracts, relationships, and other elements that impact project objectives while facing unforeseen changes [39]. Flexibility reduces the influence of uncertain events on project parties and enhances the abilities of project parties to deal with the uncertainty of the external environment. Information sharing reduces information asymmetry and conflict; solidarity enables project parties to have a common cognition and strengthen their willingness to cooperate [40]. Solidarity represents a shared expectation and helps project parties to positively maintain a long-term and stable partnership. With solidarity, project parties share tacit knowledge and experience to resolve problems to realize a common project goal. Information exchange can inhibit the opportunism caused by information asymmetry among project parties. Information exchange implies that frequent communication occurs between partners and reduces misunderstandings and conflicts, thus improving knowledge collaboration.

Trust reflects that project parties vulnerably believe that their coworkers act selflessly and obey the common cooperative agreements [41]. According to Fawad Sharif et al. (2020), a trust mechanism can provide a collaborative atmosphere in which project parties share knowledge to accomplish complicated project tasks with sufficient trust [1]. Trust curbs the opportunism wherein project parties take advantage of the opportunities without considering the other partners' interests, thus preventing a win-lose situation [36]. Hence, we propose that:

H1. *Relational norms positively influence knowledge collaboration in construction projects.*

H2. *Trust positively influences knowledge collaboration in construction projects.*

2.3. The Moderating Role of BIM Application

BIM includes the abundant parametric representation of objects and stores abundant knowledge in the form of parameters that can be exported to external databases for project parties to share knowledge [42]. Chen et al. (2022) argued that 3D models of BIM replace document-based communication approaches and strengthen the visualization and accessibility of information [22]. Azhar (2011) considered that a 4D scheduling model determines the construction sequences and integrates all resources [43]. Elghaish et al. (2019) found that 5D BIM reduces the time of quantity take-off processing and can automatically take into account every change in design [44]. As a result, BIM interprets information and knowledge for project parties and helps them to have a mutual understanding during the knowledge exchange process [45]. BIM is thus helpful for the construction industry to promote knowledge collaboration through a collaborative approach [46]. BIM application changes how project parties work and collaborate, such as knowledge and information sharing. For example, Zhang et al. (2021) proposed that the BIM application allows project parties from different organizations to develop social exchanges, access knowledge and experience from other parties, and build a collaborative environment [47]. BIM promotes the development of knowledge networks closely related to knowledge and innovation, and ensures that knowledge and innovation can be effectively diffused among network nodes [48].

BIM application enhances collaboration and communication efficiency, which helps to reduce misunderstandings and conflicts [49]. BIM allows project parties to easily access their required knowledge and information, thus reducing information asymmetry between project teams and decreasing project uncertainty and risk [50]. Gao et al. (2022) argued that consistency of the data format enables project parties to effectively curb the development of "information islands", immediately share information, decrease opportunism, and motivate them to collaborate [51]. Therefore, when the BIM application level is higher, the trust mechanism may be more efficient in improving knowledge collaboration. Previous scholars have confirmed that BIM application benefits project party collaboration [43,44]. In this case, the application of BIM technology desires implementation strategies to ensure that each project party can execute their responsibilities [40,52]. Consequently, BIM can be a helpful management approach that influences knowledge management and collaborative performance. Hence, we hypothesize:

H3. *The effect of trust on knowledge collaboration will be enhanced when the BIM application level is higher in construction projects.*

H4. *The effect of relational norms on knowledge collaboration will be enhanced when the BIM application level is higher in construction projects.*

Finally, this study puts forward a conceptual framework, shown in Figure 1.

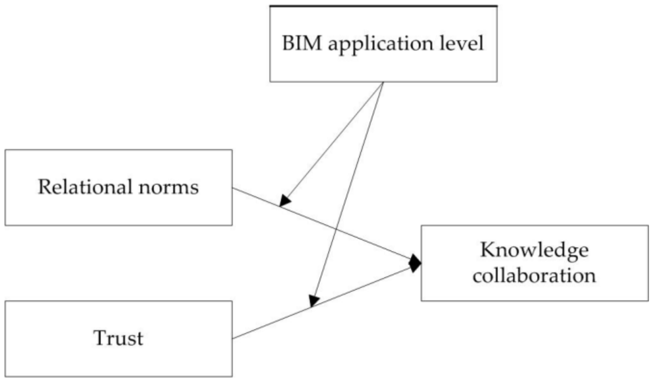

Figure 1. Conceptual framework.

3. Methods

3.1. Samples and Data Collection

A questionnaire-based survey was adopted to verify the proposed hypotheses. The questionnaire has two parts. The first section of the questionnaire obtains the respondents' basic information, e.g., female, age, education level, education field, work position, and project experience. The second part asks the respondents to score each item on a five-point Likert scale. For example, the respondents can describe the degree to which they agree with the items to describe the level of BIM technology application in their current working or performed projects. When they strongly agree, they score five points. Additionally, to mitigate the potential bias, our survey was anonymous, and the respondents' information was confidential [53].

The targeted samples worked on different construction companies in Jiangsu, Sichuan, Henan, Shanxi, Beijing, Shanghai, and Zhejiang in China. Most companies conducted construction projects involving the subway, housing, bridges, metallurgical plants, etc. The participants were the main parties, such as owners, architects, construction managers/general contractors, engineers, and consultants. They were currently working on or had performed BIM-supported construction projects and had conducted collaborative project tasks. This study used a "snowball" approach by asking the participants to provide other relevant participants. In total, 206 questionnaires were sent to the participants online. A total of 166 useful questionnaires were received, and the response rate was 80.6%. The data were mainly collected from participants working on construction projects in the following cities: Shanghai, Tianjin, Chongqing, Nanjing, Chengdu, Luoyang, Hangzhou, Xi'an, etc. The basic information about the participants is presented in Table 1.

Table 1. Demographics and profiles of respondents.

Variable	Category	Number	Percentage
Gender	Male	89	53.6%
	Female	77	46.4%
Age	Below 25	21	12.7%
	25–35	82	49.4%
	36–45	53	31.9%
	Above 45	10	6.0%
Education level	Below junior college	22	13.3%
	Undergraduate	49	29.5%
	Postgraduate	72	43.4%
	Doctor	23	13.9%
Education field	Civil engineering	57	34.3%
	Engineering management	44	26.5%
	Electrical engineering	10	6.1%
	Architecture	29	17.5%
	Building water supply and drainage	11	6.6%
	Other	15	9.0%
Work position	Staff	56	33.7%
	Manager	71	42.8%
	Senior manager	3	1.8%
	Senior specialist	7	4.2%
	Other	29	17.5%
Work experience	Below 5	55	33.1%
	5–10	55	33.1%
	11–15	34	20.5%
	Above 15	22	13.3%
Project role	Owner	39	23.5%
	Designer	33	19.9%
	Contractor	41	24.7%
	Supervisor	6	3.6%
	Material supplier	4	2.4%
	Other	43	25.9%

3.2. Measurements

The 5-point Likert scale was adopted to assess relational norms, trust, BIM application level, and knowledge collaboration, where 1 represents "strongly disagree" and 5 represents "strongly agree".

Following Lu et al. (2015), this study measured relational norms by a 9-item scale and measured trust by a 6-item scale, which have been widely used in studies in the construction fields [37].

According to Yoo (2007), this study measured knowledge collaboration using a 4-item scale to describe task-based knowledge collaboration in a complex project environment [54]. The sample item includes "The project parties carefully inter-relate actions to each other in this project".

According to Zhang et al. (2020), this study measured BIM application level by a 3-item scale [40]. The sample item includes "Fully open process with a unified project model and data integration and exchange among key contracting parties."

3.3. Common Method Bias

This study attempted to mitigate common method bias from the data collection procedure [55]. The questionnaire length was appropriately designed. Each question was explicitly described to avoid confusion, and all the responses were anonymous. Moreover, the items were ordered randomly to refrain from respondents' conjecture about our research aim. Furthermore, we applied a statistical remedy, e.g., Harman's single-factor test approach, in order to minimize the threat of common method bias [56]. As a result, our research results indicate that the contribution of the largest factor accounting for the variance was 48.587%, which was lower than 50% [55]. The results indicate no single factor to account for the majority of the variance among the measures. Consequently, common method bias might not be a significant issue in our sample.

3.4. Measurement Model

This study used the indices of construct reliability and validity to test the measurement model. The value of factor loadings, Cronbach's α, composite reliability (CR), and average variance extracted (AVE) are exhibited in Table 2.

Table 2. Measurements and reliability.

Construct and Item	Factor Loading	CR	AVE	Cronbach's α
Relational norms		0.947	0.692	0.936
1: We believe that the parties are willing to cooperate to work out solutions if an unexpected situation arises.	0.831			
2: The parties expect to be able to make adjustments in the ongoing relationship to cope with changing circumstances.	0.821			
3: The parties are consistent with the expectations of this project.	0.793			
4: The project's overall plan and the implementation scheme are shared by every party.	0.826			
5: Parties involved in this project regard each other as major partners.	0.829			
6: Exchange of information among the parties takes place frequently.	0.874			
7: We keep each other informed about events or changes that may affect the other parties.	0.800			
8: The parties establish good contact with each other, avoiding possible misunderstandings.	0.879			
Trust		0.956	0.782	0.944
1: We believe that the other parties can keep their word throughout the life of the project.	0.890			
2: We feel confident that the other parties have high levels of integrity and honesty.	0.873			
3: We believe that the other parties are competent in what they are doing.	0.884			
4: We trust that the project participants are able to fulfill contractual agreements.	0.903			
5: We are certain that the other parties have the ability to perform their tasks.	0.876			
6: We believe that the other parties could meet the requirements of the project in technology and management.	0.880			
BIM application level		0.901	0.752	0.835
1: Managed 3-D environments are established in a separate discipline BIM model in which data exchange is mainly on the basis of proprietary of exchange formats.	0.868			
2: The model contains rich data, including program data, cost information and other dimensional data.	0.832			
3: Fully open process with a unified project model and data integration and exchange among key contracting parties.	0.901			

Table 2. *Cont.*

Construct and Item	Factor Loading	CR	AVE	Cronbach's α
Knowledge collaboration		0.917	0.735	0.879
1: The project parties have a global perspective that includes each other's decisions and the relationships between them.	0.841			
2: The project parties carefully inter-relate actions to each other in this project.	0.846			
3: The project parties carefully make their decisions to maximize overall team performance.	0.878			
4: The project parties develop a clear understanding of how each business function should be coordinated.	0.862			

This study adopted factor loadings to assess indicator reliability. As exhibited in Table 2, all the factor loadings are more than the 0.70 threshold suggested in the study by Hair et al. (2013), indicating that the item reliability is acceptable [57].

Following Hair et al. (2013), this study adopted CR and Cronbach's α to test the internal consistency reliability [57]. The appropriate CR value should be higher than 0.9 and the acceptable Cronbach's α value should be higher than 0.8 [58]. Table 2 indicates that the CR and Cronbach's α values satisfy the threshold values, indicating acceptable reliability.

AVE was applied to test convergent validity. The recommended AVE threshold value should exceed 0.50 [58]. As exhibited in Table 2, the values of AVE for relational norms, trust, BIM application level, and knowledge collaboration are 0.692, 0.782, 0.752, and 0.735, respectively. All the AVE values exceed the recommended value, indicating an acceptable convergent validity for all the constructs.

Additionally, this study adopted the Fornell–Larker criterion to test the discriminant validity of the constructs. As exhibited in Table 3, the square roots of the AVE in diagonals are greater than the corresponding cross-correlations in off-diagonals, thus illustrating a satisfactory discriminant validity of the constructs.

Table 3. Discriminate validity (Fornell–Larcker criterion).

Constructs	BIM Application Level	Knowledge Collaboration	Relational Norms	Trust
BIM application level	0.867			
Knowledge Collaboration	0.607	0.857		
Relational norms	−0.063	0.487	0.832	
Trust	−0.045	0.457	0.808	0.884

3.5. Structural Model

This study used partial squares-structural equation modeling (PLS-SEM) to statistically verify the data collected by a questionnaire based on the 5-point Likert scale [57]. The PLS-SEM is suitable for this study since it can perform well with small sample sizes and non-normal data distributions. The proper sample size of this research is 166, which PLS-SEM can analyze to test the proposed hypotheses. Furthermore, PLS-SEM has a lower bias when examining the relationships between constructs [57]. The effectiveness of PLS-SEM has been confirmed in the research field of construction project management [59].

This study developed a full PLS-SEM structural model to test the hypotheses regarding the relationship among relational norms, trust, BIM application, and knowledge collaboration. This study adopted the coefficient of determination R^2 for the endogenous constructs to test the structural model, and cross-validated redundancy measure Q^2 to examine the predictive relevance of the structural model. Figure 2 shows that the R2 value is 0.656 and above 0.50 values [60]. Meanwhile, as displayed in Figure 2, the Q^2 values of the endogenous constructs are greater than 0, thus declaring that the predictive relevance of the model is appropriate [58].

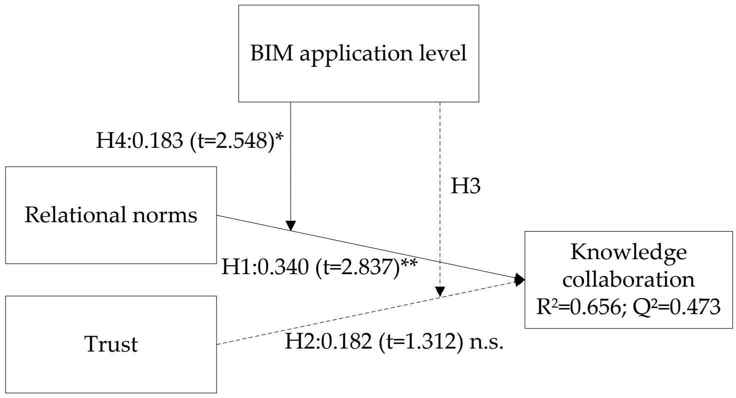

Figure 2. Results of structural model. Notes: * $p < 0.05$; ** $p < 0.01$; n.s. = not significant.

Following Hair et al. (2013) [57], the significance of the path coefficients was calculated through a bootstrapping approach with 166 cases and 5000 subsamples. Figure 2 shows that relational norms strongly influence knowledge collaboration (H1: β = 0.340; t = 2.837; $p < 0.01$), and thus H1 is supported. However, H2 is rejected because the effect of trust on knowledge collaboration is insignificant (H2: β = 0.182; t = 1.312; $p = 0.189$). Next, the moderating effect of BIM application level is tested. The moderating results reveal that H4 is supported (H4: β = 0.183; t = 2.548; $p < 0.05$), whereas H3 is not supported because of the unsupported H2 [61]. Furthermore, this study conducted a sample slope analysis to examine the moderating effect. As a result, three slopes were plotted according to the level of BIM application (at the mean, one standard deviation below the mean, and one standard deviation above the mean). As shown in Figure 3, the positive effect of relational norms on knowledge collaboration is stronger when the BIM application level is high than when it is weak. Therefore, H4 is supported.

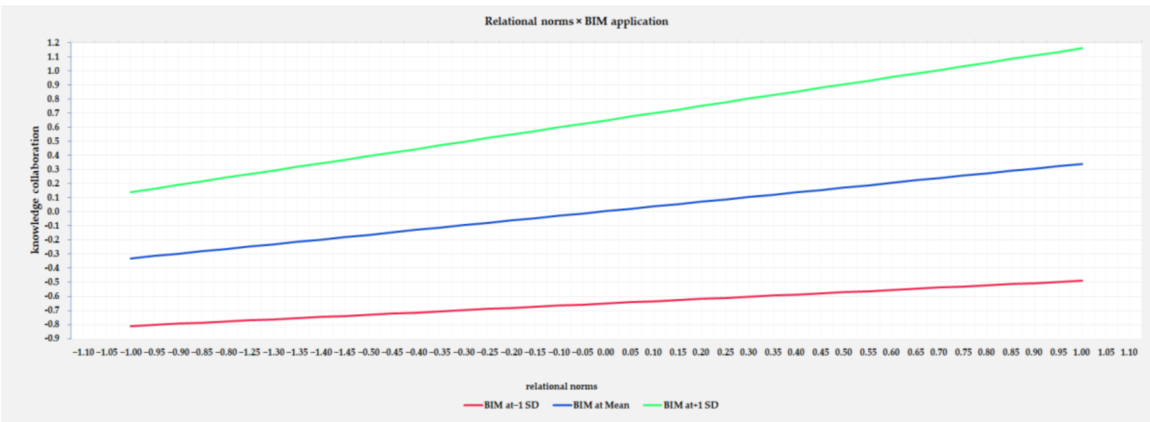

Figure 3. The moderating effect of BIM application level between relational norms and knowledge collaboration.

4. Discussion

Through the lens of relational contract theory, this study explores the relationship between relational governance and knowledge collaboration. Meanwhile, this study examines the moderating role of BIM application when relational governance affects knowledge collaboration. The following findings are discussed.

Our results found a positive relationship between relational norms and knowledge collaboration. The findings reveal that relational norms significantly influence the knowledge cooperative behavior of construction project parties when engaging in collaborative practices. For example, project parties are willing to share professional knowledge about their schedule plans with other parties in order to protect their construction schedule against project changes. In addition, the strong effect also indicates that relational governance mechanisms are more effective in promoting knowledge collaboration through which free-riding and opportunistic behaviors are ever present. This is mainly because a formal contract only offers project parties limited protections. Furthermore, it cannot identify every potential contingency, such as behavior that breaks informal agreements or oral promises that violate relational norms [50,62]. As a result, project parties are likely to obey common values and norms to adjust their behavior. Accordingly, their social relationships tend to be cooperative during knowledge exchange [37].

Additionally, our results reveal that BIM application moderates the effect of relational norms on knowledge collaboration. The findings echo the research of Oraee et al. (2019), who demonstrated that BIM technology catalyzes construction projects [28]. BIM is a valuable technology for knowledge exchange among multi-disciplinary parties, and it improves knowledge collaboration by transferring and translating information [63]. According to Zhang et al. (2020) [40], project parties could establish a strategic framework to illustrate the explicit tasks and obligations of the project parties using BIM technology. Next, project parties should follow the strategic framework and fulfill their respective obligations. This implies that a high level of BIM application reinforces the deployment of relational norm mechanisms in enhancing knowledge collaboration.

In contrast, the direct path shows that the trust mechanism has an insignificant influence on knowledge collaboration. Contrary to the research of Bond-Barnard et al. (2018) that trust predicts collaboration level [64], our findings consider that the effect of trust on knowledge collaboration may not always be effective and context-free, especially in construction projects. Trust implies that project parties should have a common sense and perception, for example, having a shared objective which is also a positive collaboration process [8]. However, it is not easy to develop a trusting relationship among multi-disciplinary project parties in the short term because of the temporary organizational structure and short-term orientation of construction projects [10]. Consequently, parties may hesitate to share their knowledge with others in order to maintain sustainable competitive advantages.

5. Conclusions

Prior studies have confirmed that formal contracts foster the cooperative behavior of project parties by defining responsibilities and roles, setting the partnership's goals, and promoting communication [11]. Despite being bound by contracts, knowledge collaboration cannot fulfill the expectation of the objectives of construction projects, since some potential contingencies (such as opportunism) cannot be identified by a formal contract. Through empirical study, our study confirms the effectiveness of relational governance on knowledge collaboration in construction projects.

Relational governance assures that knowledge, especially tacit knowledge, can be integrated and diffused through cross-organizational boundaries in a short time in temporary structures in construction projects [30,65]. Thus, we advise that project managers help project parties to develop a knowledge network to accelerate the flow of knowledge. They can foster a culture of sharing in order to encourage knowledge sharing, because a sharing culture can serve as an informal social norm that intensifies some elements of human nature (e.g., fulfillment, altruism, and reciprocity) [66]. Based on coordination theory, project managers should learn how to manage well the coordination processes, i.e., sharing resources, task dependencies, consumer/producer relationships, and simultaneity constraints [67].

Finally, our research results demonstrate that the level of BIM application affects the effect of relational governance mechanisms on knowledge collaboration. Our research findings show that the external context dramatically affects the effectiveness of relational governance mechanisms and ultimately fosters knowledge collaboration. This leads to the emergence of alternative governance mechanisms that span new boundaries [63]. In other words, BIM application reconfigures a collaborative environment, redefines social relationships, and transforms industry practices [68]. Therefore, with the emerging BIM-supported projects, key parties should adjust their current work roles and routines by proper training to adapt to the new BIM-supported collaboration. Furthermore, project managers can actively build a strategic framework to help project parties develop BIM-specific obligations and roles to improve the BIM application level and ultimately to improve the collaborative performance of construction projects.

6. Limitations and Future Research

Our study still has certain limitations. The study was performed in the Chinese construction industry, in which the level and scope of BIM technology application are relatively low, and the respondents cannot have an in-depth understanding of BIM. Future studies may be performed with broader samples to generalize our findings and increase their applicability to other contexts. This study only explored the influence of relational governance on knowledge collaboration. Future studies could examine the interactive effect of contract and relational governance on knowledge collaboration with the moderating role of BIM application. Additionally, one interesting direction for future research could be to explore the impact of knowledge collaboration on project performance. Meanwhile, BIM technology serves as a knowledge and information repository. It is necessary to further explore how it impacts knowledge collaboration in construction projects in the future.

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Abbreviations

BIM	building information modelling
CR	composite reliability
AVE	average variance extracted

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