ISSN 1392-3730/eISSN 1822-3605

JOURNAL of CIVIL ENGINEERING and MANAGEMENT

2024
Volume 30
Issue 6
Pages 494–507
https://doi.org/10.3846/jcem.2024.21267

TECHNOLOGICAL INNOVATION COOPERATIVE BEHAVIOR ANALYSIS FOR MEGA CONSTRUCTION PROJECTS BASED ON TPB

Zhenxu GUO, Qing'e WANG✉

School of Civil Engineering, Central South University, 22 Shaoshan South Road, Tianxin District, Changsha 410083, People's Republic of China

Article History:
- received 31 July 2023
- accepted 11 January 2024

Abstract. Due to the complex nature of mega construction projects (MCPs), technological innovation risks have significantly increased. Cooperation is widely accepted as a proactive approach to resolving these risks. An in-depth study of technological innovation cooperative behavior (TICB) helps understand the underlying reasons, but studies need to pay more attention to it. This study explored the factors affecting TICB for MCPs and developed a conceptual model based on the Theory of planned behavior (TPB). It established a structural equation model to verify the relationship between influencing factors. An example verified the feasibility of the model. The results show that cooperative attitude, subjective cooperative norm, perceived cooperative behavior control, and cooperative scenarios positively affect cooperative behavior through cooperative intention. Cooperative attitude plays a mediating role between cooperative scenarios and cooperative intention. Perceived cooperative behavior control has no direct effect on cooperative behavior. This study provides a theoretical reference to guide future empirical studies and enriches the knowledge of TICB for MCPs.

Keywords: technological innovation, cooperative behavior, mega construction projects, theory of planned behavior, structural equation model.

✉Corresponding author. E-mail: *wqecsu@126.com*

1. Introduction

Mega construction projects (MCPs) are "super" infrastructure projects due to their unique, complex, and systematic nature (Flyvbjerg, 2014). More to this, due to the ever-growing importance and expansion, they can come to the point of affecting the goals since technological innovation would incur risks to stakeholders in the process of research, transformation, and industrialization (Shukra et al., 2021). Many factors hinder the technological innovation of MCPs, including the uncertain environment, the complex projects, and the limited innovation ability (Ma & Fu, 2020). These cannot be held as evidence against technological innovation in MCPs since it is vitally important to the development of the nations. Technological innovation cooperation behavior (TICB) provides a direction to resolve these conflicts.

However, MCPs emphasize communication, coordination, and partnership (Sun & Zhang, 2011). This brings us to the conclusion that the stakeholders make them (i.e., leadership, risk, and relationship) inevitable to regard as an essential part of TICB for MCPs (Aladag & Isik, 2019; Zaman et al., 2022). The interaction among stakeholders of TICB is worth further exploration (Liu & Ma, 2021; Noktehdan et al., 2019). The success of any MCPs lies in the TICB of individuals and organizations (Hu & Diao, 2021), in addition to the upstream and downstream of the industrial chain. Understanding cooperative relationships among universities, research institutes, contractors, owners, design units, and other stakeholders is the basis for solving scientific issues (Dong & Martin, 2017). They should also broaden their concern to highlight cooperative behavior (CB) (Coenen & Lopez, 2010).

For MCPs with a complex organizational structure, TICB usually involves multiple stakeholders (Du et al., 2022). Due to their different roles, stakeholders must clarify the attitudes, values, and goals in the process of TICB. The theory of planned behavior (TPB) helps researchers understand how these factors affect the behaviors of the stakeholder (Betts et al., 2011; Neto et al., 2020). By illustrating how intentions translate into behavior, researchers can better grasp the dynamic factors in the cooperation process and guide for solving cooperation issues (Ajzen, 2020). To fill the knowledge gaps, this study aims to explore the influencing factors of TICB for MCPs based on TPB and the relationship among them.

The structure of this study is organized as follows. We discuss the related literature review and hypotheses in Section 2. Section 3 interprets the research methodologies. In Section 4, this study identifies factors and then discusses the relationship among factors in Section 5. Finally, Section 6 concludes this study.

2. Literature review and hypothesis

TPB is Ajen's extension of the theory of rational behavior (Ajzen, 2020). The theory mainly predicts and interprets individual behavior and decision-making processes (Neto et al., 2020). Behavioral attitude, subjective norm, and perceived behavioral control affect behavioral intention. Exact perceived behavior control can predict the possibility of actual behavior. Behavioral intention directly affects actual behavior (Ajzen & Kruglanski, 2019; Hagger et al., 2016; Scuotto et al., 2020). Although TPB was initially proposed at the individual level, it also has some applicability to research at the organizational level, which can help us better explain organizational behavior (Johnson & Hall, 2005; Zheng et al., 2018).

The predictive effect of TPB on TICB has been confirmed by a series of studies (Nieto & Santamaria, 2010; Sendstad et al., 2023). Under the TPB framework, TICB highlights cooperative intention (CI) rather than cooperative effect. CI refers to the motivation of technological innovation stakeholders for MCPs to carry out CB and their willingness to cooperate (Yi & Zhang, 2022). Targets and intentions drive organizational behavior (Scuotto et al., 2020; Xiong et al., 2021). TPB deems how stakeholders shape cooperative attitude (CA), subjective cooperative norm (SCN), and the perceived cooperation of behavior control (PCBC), thus influencing CI and CB (Ajzen, 2020). To realize the innovation goal, technological innovation stakeholders with positive CA, SCN, and PCBC carry out the organization mode of long-span resource integration. Owners drive other stakeholders to innovate and provide information for the innovation activities (Zhu et al., 2020).

Specifically, CA expresses the probability of the feasible result of TICB and the subjective evaluation of the outcome or experience. SCN comes from the influence of others' opinions, manners, and behaviors. PCBC is the sense of difficulties and obstacles before technological innovation stakeholders cooperate (Lee & Kim, 2018). In addition, many scholars have discussed selecting technological innovation stakeholders, analyzing influencing factors, and formulating cooperation strategies from interdisciplinary, cross-industry, and cross-sector perspectives (Zhang & Tang, 2017; Zhu et al., 2021). They reveal that internal R&D cooperation is an effective management strategy to promote enterprise innovation (Zhang & Tang, 2017). External environment orientation accelerates R&D partnerships (Li & Wang, 2022). Therefore, it is meaningful to consider the essential characteristics of TICB and the expansion of TPB. The significant influence of cooperative scenarios (CS) such as policy, economy, talent, and technology on the CA and CI of technological innovation is also worth exploring (Jain et al., 2020; Zhang et al., 2022). Corresponding to the above, this study attempts to construct a comprehensive framework to explore how CA, SCN, PCBC, and CS affect TICB. It is also a research gap to be solved in this study.

In the process of technological innovation for MCPs, conflicts of objectives and interests restrict the stakeholders from cooperating. When technological innovation damages one party's interests and increases the other's claims, the negative CA of technological innovation stakeholders will affect CI and CB. The technological innovation stakeholders on issues such as improper interest distribution, unclear risk sharing, and incomplete information exchange will inhibit CI (Yang et al., 2020). When they provide sufficient input and allocation, other stakeholders will be absorbed in advancing the collaboration (Cai et al., 2020).

Based on the above analysis, the following hypotheses are proposed:

H1: CI will mediate the relationship between CA and CB.

H2: CI will mediate the relationship between SCN and CB.

H3: CI will mediate the relationship between PCBC and CB.

MCPs are highly valued by the government, and the relevant policies address the promotion of TICB (Chen et al., 2020). The government provides special funds to ensure the smooth implementation of technological innovation for MCPs. Policy investment is made to protect TICB. These policies decrease the potential risks of innovative activities, making technological innovation stakeholders in CA and CI more positive (Wang et al., 2021). MCPs with complex geological terrain, needy working environments, and rugged construction conditions inevitably lose core technology talents (Sun & Zhang, 2011). Considering the complex work of MCPs, the talent shortage will negatively impact CA and CI for the operation process. A team with high cohesion, high efficiency, and high quality will help further ensure cooperation. Technological innovation for MCPs is constantly pioneering, and the stakeholders' cooperation requires technological input as the basis (Zhu et al., 2018).

Based on the above analysis, the following hypotheses are proposed:

H4: CA will mediate the relationship between CS and CI.

H5: CI will mediate the relationship between CS and CB.

Benefit distribution and risk sharing are the key points of cooperation, and CB pays more attention to equity than efficiency. On the one hand, the benefits of technological innovation for MCPs are reflected in the new equipment and technology. Benefit distribution will eventually be transformed into the ownership of intellectual property rights. Rational division of intellectual property rights encourages more vigorous participation in cooperation. On

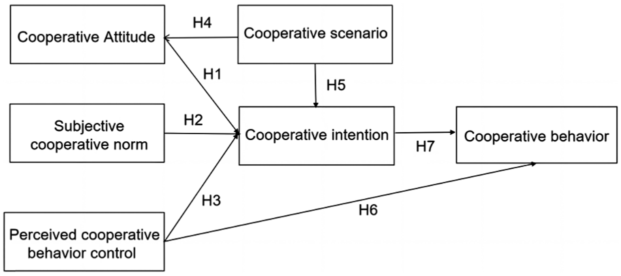

Figure 1. The theoretical model of TICB for MCPs

the other hand, a reasonable determination of the risk bearers and the proportion to bear can reduce the probability of risk occurrence and loss, which controls the cost of risk management and maximizes the benefit of technological innovation (Aladag & Isik, 2020). To some extent, the stronger the CI of technological innovation stakeholders, the more effort they will make to practice MCPs. It can even be understood that the CI directly determines the CB of technological innovation stakeholders (Segarra-Cipres et al., 2014).

Based on the above analysis, the following hypotheses are proposed:

H6: PCBC has a positive effect on CB.

H7: CI has a positive effect on CB.

The theoretical model of this study is shown in Figure 1.

3. Methodology

3.1. Research flowchart

This study adopted a mixed research method, including four main stages (see Figure 2).

Firstly, this study inspected the TICB in five MCPs (three tunnel projects and two bridge projects) in China through interviews, network meetings, and group discussions. The five projects are located in unique geographical sites. The region has nine characteristics: significant topographic elevation difference, complex geological structure, vigorous seismic activity, frequent mountain disasters, rough climatic conditions, fragile ecological environment, weak infrastructure, scarce social resources, and sensitive religious beliefs. Our interviewees were selected according to pre-determined standards. They were mainly liable for the technological innovation of the work site and the research of "four new" technologies (new technology, new approach, new materials, and new equipment).

The survey was conducted in a group format. The first field survey conducted in-depth research on the technological innovation and application of the project in August 2022, including an intelligent toxic gas detection robot and intelligent radar detection vehicle. Combined with the relevant literature, we designed the interview outline. From August to September 2022, the weekly network meeting will be held. The group invited several experts from Northeastern University, Central South University, and China Academy of Railway Sciences Group Limited to discuss the scientific and measurable nature of the questionnaire indicators and form a preliminary questionnaire. In October 2022, the group conducted the second field survey, interviewing relevant staff in the five projects. Each discussion lasted 1–1.5 hours. The group members discussed and got the final questionnaire according to the interview results. Please refer to the Appendix for the detailed questionnaire.

Secondly, the group summarized the collected data, which became the foundation of the theoretical model. Based on TPB and combined with the practice of MCPs, this study established the index system of influencing factors of TICB for MCPs. The system includes CA SCN, PCBC, CI, and CS, as shown in Table 1. The group invited five experts undertaking relevant tasks in MCPs to conduct a pilot survey. The experts responded to questions in the questionnaire for more than ten minutes. By collecting experts' opinions on the factors affecting the TICB for MCPs, the research verified the appropriateness and completeness of the questionnaire items.

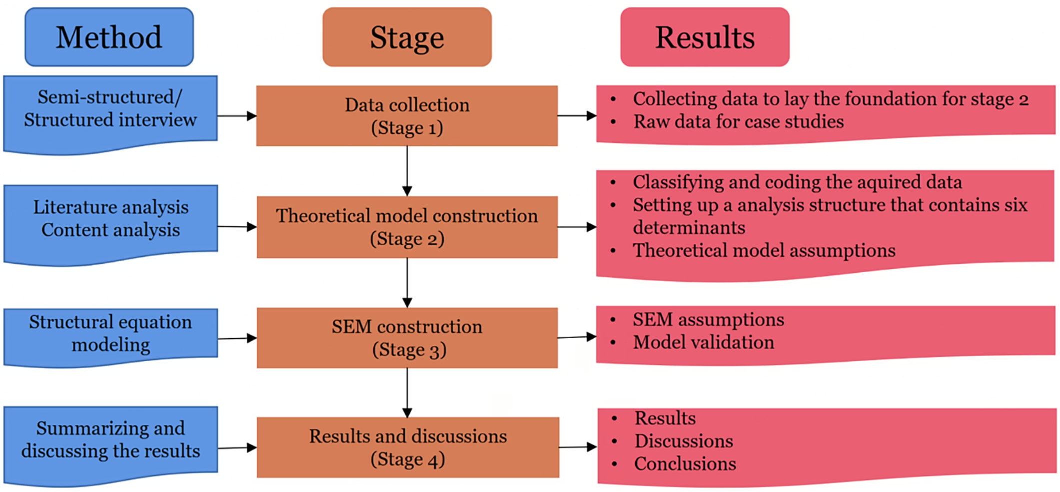

Figure 2. Research flowchart

Table 1. Determinants for TICB in MCPs

Groups	Factors	1	2	3	4	5	6	7	8	9	10	11	12
CA	CA1 Satisfaction	✓	✓		✓	✓		✓	✓	✓	✓		
	CA2 Trust	✓	✓		✓		✓					✓	
	CA3 Expected return	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SCN	SCN1 industry impact	✓			✓	✓	✓		✓	✓		✓	
	SCN2 Others influence	✓			✓	✓	✓		✓	✓	✓	✓	
	SCN3 Own actual situation	✓		✓	✓		✓	✓	✓	✓	✓	✓	
PCBC	PCBC1 Responsible attribution					✓	✓		✓	✓		✓	✓
	PCBC2 Perceived risk	✓	✓	✓		✓		✓			✓		
	PCBC3 Time pressure							✓				✓	✓
CI	CI1 Innovative consciousness				✓	✓	✓		✓				
	CI2 Innovative demand				✓	✓	✓		✓				✓
	CI3 Publicity and promotion						✓					✓	
	CI4 Extend cooperation							✓		✓	✓	✓	
CS	CS1 Policy support			✓			✓		✓	✓			
	CS2 Economic input			✓					✓	✓		✓	
	CS3 Talent investment			✓			✓		✓	✓			
	CS4 Technical support			✓					✓	✓			✓
CB	CB1 Cooperative network		✓			✓	✓			✓		✓	
	CB2 Cooperative frequency		✓							✓			
	CB3 Cooperative duration		✓					✓		✓		✓	

Note: 1 – Ashaduzzaman et al. (2022); 2 – Huang et al. (2021); 3 – Ma et al. (2022); 4 – Shou et al. (2023); 5 – Long et al. (2017); 6 – Hau and Kim (2011); 7 – Xiong et al. (2021); 8 – Yuan et al. (2018); 9 – Yan et al. (2020); 10 – Li et al. (2018); 11 – Zheng et al. (2018); 12 – Adriaanse et al. (2010).

Thirdly, the Structural equation model (SEM) of the influencing factors is built. It is a multiple statistical analysis method used to test a set of hypotheses about the relationship among variables, and it evaluates two models: the measurement model and the structural model. The measurement of these unobserved variables is discussed before discussing the relationship among the latent variables. SEM uses Confirmatory Factor Analysis (CFA) to assess the measurement model. Model fit is evaluated for CFA to validate the measurement. Through the results of CFA, the questionnaire can be properly evaluated, including the rationality of the question setting and the reliability and validity of the questionnaire. Once the model fit is done, the structural model among the latent variables is assessed. The structural model reveals relationships among latent variables. These relationships are examined by path analysis (a particular type of multiple regression analysis). In path analysis, we make assumptions about direct and indirect effects and then use statistical methods to test whether these assumptions hold. If the effect is consistent with the hypothesis, the model is supported. Otherwise, the hypothesis needs to be revised and tested. The model includes six latent variables and 20 apparent variables. CS, CA, SCN, and PCBC are premise variables, CA and CI are intermediate variables, and CB is the outcome variable. AMOS software tested and verified its validity.

Finally, we summarized and discussed the analysis results, and this study's theoretical and practical implications were proposed.

3.2. Data collection and analysis

After the pilot study, from February to March 2023, the group distributed questionnaires to professionals through face-to-face interviews, Tencent conference interviews, and questionnaire magnitude. This study illustrated factors to ensure the accuracy of understanding. For example, "Satisfaction" refers to the degree of satisfaction with the technological innovation subject to the existing cooperative relationship. "Responsible attribution" means that the stakeholders are liable for the adverse consequences caused by the CB and earnestly perform the contract. "Perceived risk" refers to the uncertainty and adverse consequences the subject cooperation perceives. "Publicity and promotion" refers to whether the subject is willing to publicize the positive effects of TICB. "Cooperative duration" refers to whether the subjects are eager to go all out to achieve the tasks undertaken in the TICB and continue to cooperate in the construction of future engineering projects. "Cooperation network" refers to the interdependent relationship between technological innovation cooperation stakeholders and the realization of project construction objectives through coordination. The questionnaire consists of three parts:

(1) Basic information of the interviewee (work experience, responsibilities undertaken in the project, type of company).
(2) Respondents' attitudes towards the importance of 20 influencing factors were measured by Richter's five-level scale (1= very unimportant, 2 = unimportant, 3 = average, 4 = important, 5 = very important).
(3) Opening questions.

Out of 226 responses, the question "time is taken to fill in 60 seconds", the scale score is the same, the same item score is the same, the score is regular, there are 202 effective questionnaires, and the effective rate is 89.38%. The number of valid questionnaires was more than ten times the maximum item, and the samples encountered the recommended standards for statistical analysis (Hair et al., 2012). SPSS software made a statistical analysis of the questionnaire data. It can be seen from Table 2 that 81.19% of the respondents held junior management positions or above and had an excellent educational background. Additionally, all practitioners have some experience in TICB for MCPs, further ensuring data quality.

4. Results

4.1. Descriptive statistics on sample data

The descriptive statistical analysis mainly reveals the data distribution of observed variables, including the number of samples, mean value, standard deviation, skewness, and peak value. In 202 questionnaires, the respondents' scores on the items are on a scale of 1–5, with the mean [3.68, 4.17] and standard deviation [0.886, 1.119]. The overall distribution is reasonable. In the test of normal distribution, the absolute values of skewness coefficients and kurtosis coefficients are <3, conforming to normal distribution.

4.2. Data reliability and validity test

Cronbach's α coefficient tests the scale's internal consistency. According to the questionnaire reliability and validity test results, the corrected item total correlation of all items is > 0.4. The Cronbach's α coefficients of the whole scale and variables are > 0.8, indicating that the questionnaire has internal consistency.

The Kaiser-Meyer-Olkin and Bartlett spherical test results demonstrates that the KMO value of the whole scale and variables are > 0.7. The significance value Sig. is < 0.05, indicating that the scale data are suitable for the factor analysis. The factor analysis results shows that the cumulative variance interpretation rate of the six factors is 58.494% > 50%, indicating that the six factors could effectively extract the item information.

4.3. Convergent validity and discriminant validity test

In order to ensure the validity and rationality of the measurement model, convergent validity and discriminant validity should be tested. The convergent validity test results are shown in Table 3. AVE (>0.5), CR (>0.7), and P(<0.001) are reasonable. The measurement indexes of latent variables have good internal consistency. The discriminant validity test results are shown in Table 4. Each factor's AVE square root value (0.769, 0.838, 0.769, 0.795, 0.857, 0.754) exceeds "the maximum value of the correlation coefficient between the factor and other factors", indicating good discrimination validity.

4.4. Model fitting tests

This study constructed a SEM to investigate further the relationship among the latent variables in the conceptual model shown in Figure 1. According to the theoretical model and relational hypothesis, the sample data was imported into Amos 22.0, and the standardized path coefficients of the model were obtained through analysis, as shown in Figure 3. Based on the path coefficient and influence significance between variables, the "CB←PCBC" standardized path coefficient is 0.003, P = 0.847 > 0.05. It indicates that the path has no decisive influence and should be deleted. Therefore, the model needs to be revised.

Table 2. General information of the respondents

Respondents	Categorization	Number	Percentage
Types of the enterprises	Owner	36	17.82%
	Contractor	78	38.61%
	Universities & research institute	60	29.71%
	Other (government)	28	13.86%
Related work experience	1–3 years	132	65.35%
	4–7years	60	29.70%
	> 8 years	10	4.95%
Position in the project or enterprise	Technical personnel	38	18.81%
	Ordinary management	88	43.57%
	Senior management	76	37.62%
Education background	Bachelor	96	47.52%
	Postgraduate	100	49.51%
	Other	6	2.97%

Table 3. Convergent validity test results

Latent variable	Measurement index	Standardized path coefficient	Non-standardized path coefficient	S.E.	P	CR	AVE
CA	CA1	0.755	1	0.000	***	0.812	0.591
	CA2	0.846	1.117	0.105	***		
	CA3	0.699	0.935	0.101	***		
SCN	SCN1	0.776	1	0.000	***	0.838	0.632
	SCN2	0.803	1.025	0.097	***		
	SCN3	0.806	1.087	0.103	***		
PCBC	PCBC1	0.813	1	0.000	***	0.876	0.702
	PCBC2	0.837	1.022	0.08	***		
	PCBC3	0.863	1.035	0.08	***		
CI	CI1	0.836	1	0.000	***	0.917	0.735
	CI2	0.858	1.009	0.067	***		
	CI3	0.887	1.039	0.066	***		
	CI4	0.847	0.974	0.066	***		
CS	CS1	0.818	1	0.000	***	0.848	0.592
	CS2	0.707	0.76	0.069	***		
	CS3	0.949	1.133	0.074	***		
	CS4	0.545	0.596	0.074	***		
CB	CB1	0.762	1	0.000	***	0.798	0.568
	CB2	0.77	1.289	0.128	***		
	CB3	0.728	0.977	0.102	***		

Note: *P < 0.05, **P < 0.01, ***P < 0.001.

Table 4. Discriminant validity test results

Latent variable	CS	PBC	CA	SN	CI	CB
CS	0.769					
PBC	0.000	0.838				
CA	0.637	0.000	0.769			
SN	0.000	0.000	0.000	0.795		
CI	0.450	0.347	0.503	0.303	0.857	
CB	0.350	0.270	0.392	0.236	0.778	0.754

After model modification, the proper calculation of the model was carried out, and the fitting indexes of the structural equation model are shown in Table 5. The index values of GFI = 0.968 > 0.9, AGFI = 0.929 > 0.9, NFI = 0.908 > 0.9, RFI = 0.960 > 0.9, IFI = 0.931 > 0.9, CFI = 0.926 > 0.9, X^2/df = 1.975 < 3, RMSEA = 0.070 < 0.08, and RMR = 0.029 < 0.05, indicating that the constructed conceptual model is good.

4.5. Direct effect test

The revised model test results are shown in Figure 4. According to the path coefficient and influence significance between variables, the direct effect hypothesis is verified. The standardized path coefficient of the direct effect of CI on CB is 0.776, P < 0.001, indicating that CI have a statistically significant positive effect on CB. Therefore, the original hypothesis is accepted, and H7 is established. The estimated values of the parameters are acceptable statistics.

Table 5. Model fitting test results

Category of fitting index	Name of the fitting indicator	Statistical value	Fit condition
Absolute fitness index	X^2/df	1.975	✓
	GFI	0.968	✓
	AGFI	0.929	✓
	RMR	0.029	✓
	RMSEA	0.070	✓
Value-added fitness index	NFI	0.908	✓
	RFI	0.960	✓
	IFI	0.931	✓
	CFI	0.926	✓
Reduced fitness index	PGFI	0.426	✓
	PNFI	0.408	✓
	PCFI	0.409	✓

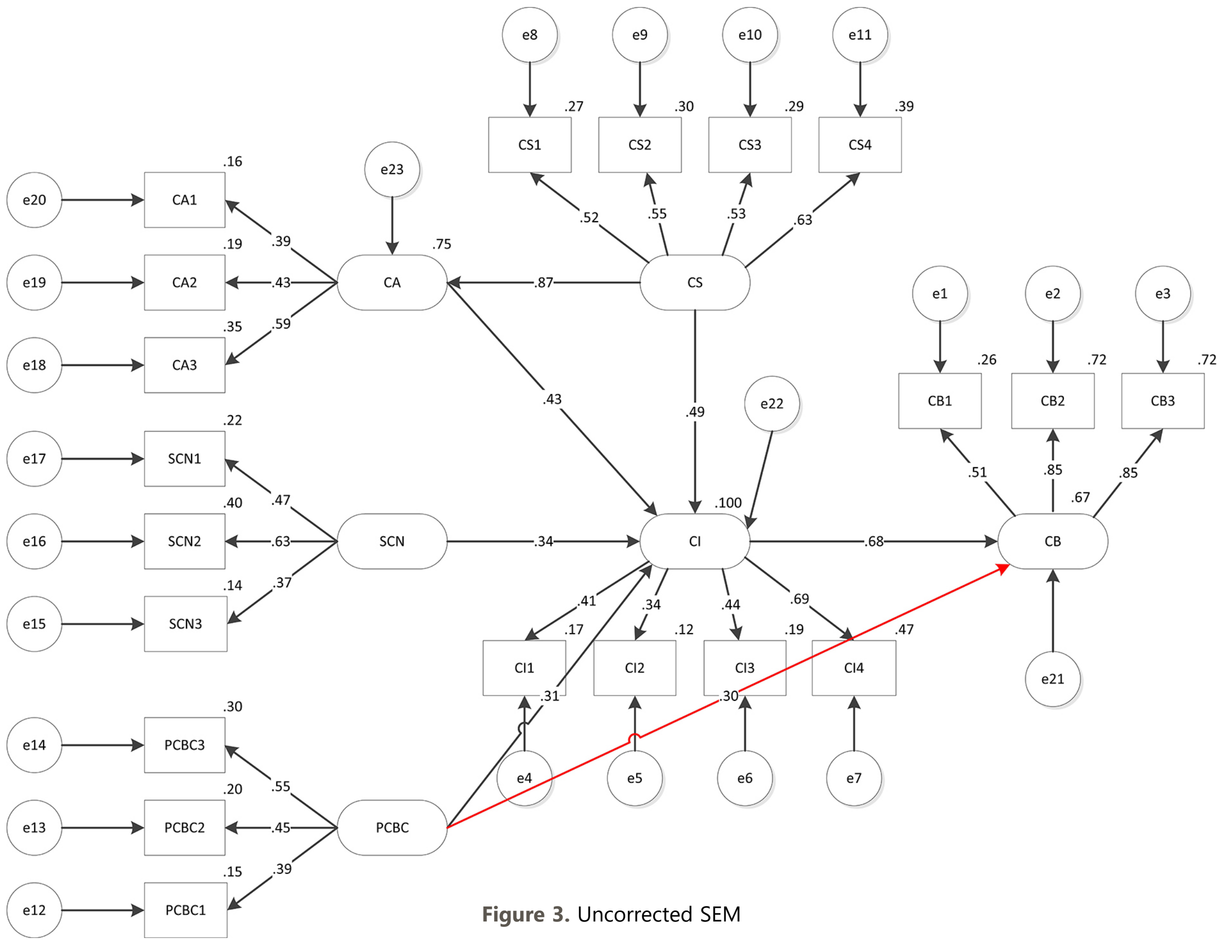

Figure 3. Uncorrected SEM

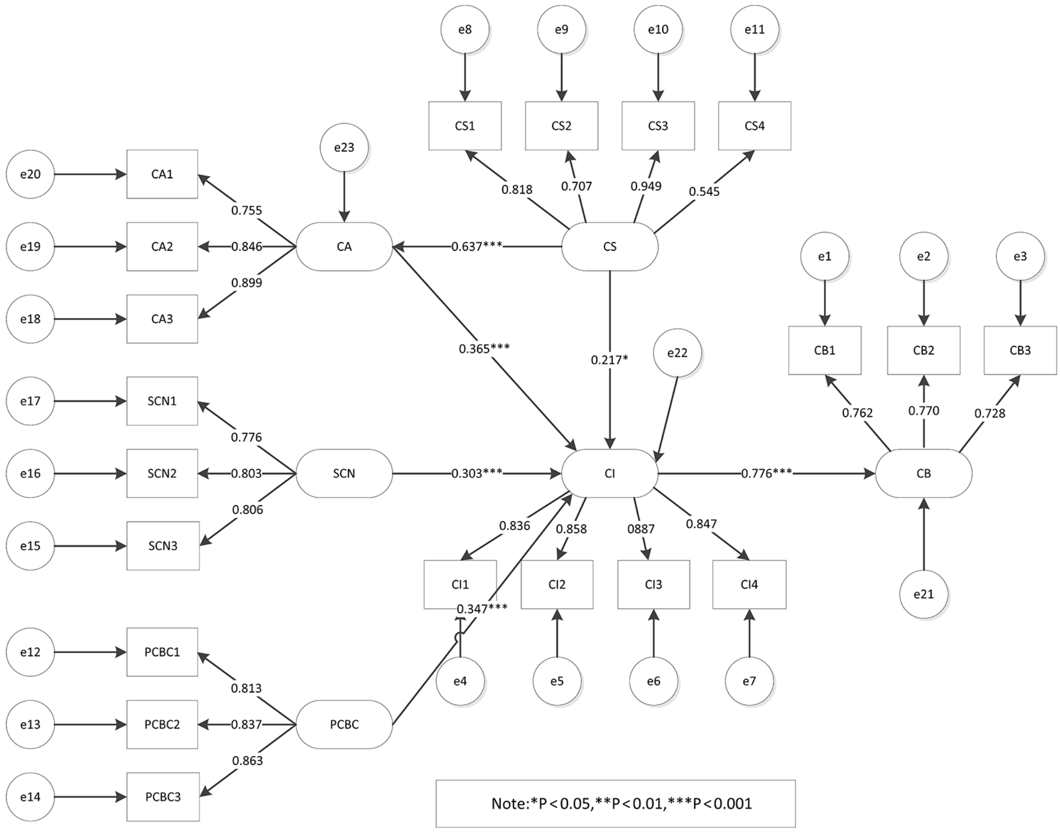

Figure 4. Modified SEM

The factor load of latent variable on the observed variable is positive, indicating that it has a statistically significant positive effect. The factor loads of the four observed variables of CI are 0.836, 0.858, 0.887, and 0.847, respectively. The factor loads of the three observed variables of PCBC are 0.813, 0.837, and 0.863, respectively, indicating that the reliability of the two measurement models is good. As for the standardized regression coefficients β in the measurement models of CA, SCN, and CB are all located at [–1, 1], and the parameters estimated by the model are reasonable.

Considering the large number of abbreviations in this study, the variables and abbreviations are set to facilitate the understanding of readers and researchers, as shown in Table 6.

Table 6. Variables and their abbreviations

Variables	Abbreviations
Mega construction projects	MCPs
Technological innovation cooperative behavior	TICB
Cooperative behavior	CB
Cooperative attitude	CA
Cooperative intention	CI
Subjective cooperation norm	SCN
Perceived cooperative behavior control	PCBC
Cooperative scenario	CS

4.6. Mediating effect test

Currently, the academic circle uses the product of Bootstrap direct test coefficient to test the mediating effect. This study tested the mediating effect using Bootstrap in Amos 22.0. Two thousand samples were set. Set the confidence level to 95% in both bias-corrected confidence intervals and percentile confidence intervals in Table 7.

Table 7 shows that in the intermediate path CS→CI→CB, the standardized indirect effect coefficient is 0.350, 95% bias-corrected confidence intervals are [0.185, 0.525] between low and high values, and 95% percentile confidence intervals. The low and high intervals are [0.183, 0.522], excluding 0, and P values are less than 0.001, indicating that CI will mediate the relationship between CS and CB. Therefore, the original hypothesis is accepted, and H5 is valid. The same applies to H1, H2, H3, and H4.

5. Discussion

Technological innovation stakeholders of MCPs are a growing organization. Cooperation improves the efficiency of technology transfer. It plays a positive role in the success of technological innovation. Nevertheless, more attention should be paid to accelerating cooperation to promote technological innovation. Therefore, we examined how CA, SCN, and PCBC affect CB, whether CB is directly affected by PCBC and CI, and the potential impact of CS.

Trust has been in the spotlight since the public realized it would affect cooperative intensity, quality, and value (Liao & Long, 2019). Researchers have highlighted illustrating and validating the significance of close partnerships. However, trust requires addressing improving the initiative of CA and improving the effect of technological innovation by influencing CI (Zhao et al., 2014). Based on TPB, the standardized path coefficient of trust on CA is 0.846, better than the satisfaction and expected income measurement effect. It shows that trust is an important indicator to improve the enthusiasm of CA for MCPs, which emphasizes that companies increase collaborative trust in reaction to conflict in innovation ecosystems to influence CB by improving CI. Companies that are less connected or have complementary technologies of value are likely to expand their cooperation over well-connected companies or technology competitors. Companies with trust may seek opportunities for collaboration (Jones et al., 2021).

Due to the characteristics of complex technology, tremendous project volume, numerous stakeholders, and long construction periods, potential dangers and disasters may bring technological innovation risks for MCPs. Faced with these risks, companies will take different approaches to whether to cooperate. Enterprises should consider their resource conditions and technical capabilities to optimize resource allocation. When technological innovation stakeholders have technological advantages, knowledge resources, learning ability, and innovation experience, they can effectively exchange knowledge in cooperation and are more inclined to cooperate. Responsible attribution, perceived risk, and time pressure are 0.813, 0.837, and 0.863 respectively. Technological innovation cooperation can solve the issues resulting in these potential variables. They cover the perception of tasks, roles, responsibilities, and decision-making. Stakeholders are subject to cooperation when they have greater decision-making power.

Table 7. Bootstrap analysis of mediating effect

Model path	Standardized effect value β	95% bias-corrected confidence intervals			95% percentile confidence intervals			Hypothesis testing
		Lower	Upper	P value	Lower	Upper	P value	
CA→CI→CB	0.284	0.072	0.556	**(0.009)	0.060	0.534	*(0.012)	✓
SCN→CI→CB	0.236	0.073	0.478	**(0.001)	0.072	0.475	**(0.001)	✓
PCBC→CI→CB	0.27	0.124	0.455	**(0.001)	0.102	0.431	**(0.001)	✓
CS→CA→CI	0.232	0.069	0.516	**(0.006)	0.046	0.473	*(0.012)	✓
CS→CI→CB	0.350	0.185	0.525	***	0.183	0.522	***	✓

Note: *P < 0.05, **P < 0.01, ***P < 0.001.

They are willing to make efforts for the realization of cooperation aims. This is consistent with a current study. It proves that SCN can enhance the awareness of information sharing and knowledge exchange among members, making cooperation more possible. CA of some innovation stakeholders will affect the enthusiasm of others to cooperate with them, thus affecting the work docking and work quality (Peng & Chan, 2019; Yan et al., 2020).

Technological innovation stakeholder cooperation is a complex game relationship. Cooperation is subject to institutional constraints. Technological innovation stakeholders of MCPs should consciously fulfill their contractual obligations, reduce opportunistic behavior, avoid taking advantage of information asymmetry for speculation, reduce MCPs risk and time stress, and enhance the stability of cooperation (Helm & Kloyer, 2004). It was also confirmed in this study, which clarified the positive and significant effects of responsible attribution, perceived risk, and time pressure on PCBC. Establishing a precise risk-sharing ratio and benefit-sharing mechanism for TICB is crucial. This study points out that PCBC will affect the amounts of resources invested in cooperation, the degree of innovative efforts, and the choice of opportunistic and reciprocal behaviors but will not directly decide whether to cooperate. Technological innovation risks are brought about by organizations' different natures, motives, and goals, improper distribution of benefits, needy information exchange, and other problems (Delbufalo, 2015). For example, in the process of TICB for MCPs, the application of technological innovation results will generate data that can obtain practical benefits through the standardized processing of the platform (Li & Wang, 2022). If the interface correlation degree of technological innovation achievements is low, it is not easy to convert data into information. Enhancing CI to reduce the risk of technological innovation is an inevitable choice for each project to adopt a digital and visual inspection system and form an integrated construction and maintenance management (Zhao et al., 2022).

Governments play an essential role in technological innovation cooperation. Relevant research clarified the importance of government policy inputs and the direction for the government to decide on MCPs. The model fitting results showed that the correlation coefficient between policy support and CS was 0.818, which reveals that policy support is conducive to creating a good atmosphere for innovation cooperation. It can incentivize stakeholders to promote CI and improve cooperation enthusiasm. It guarantees the smooth development of technological innovation activities in resource acquisition, innovation transformation, and achievement application (Ozorhon, 2013; Sparrevik et al., 2018). The technological innovation of MCPs should be closely related to the actual engineering and effectively serve the needs of the field. This puts forward higher requirements for investing funds, talents, technology, and other aspects required in technological innovation activities. We have noticed that the technological innovation stakeholders will adjust the choice of subject behavior in the face of CS changes. A good CS will create a healthy atmosphere for innovative cooperation. Geographically located businesses may have a basis for mutual trust, generating positive CA and CI. It enables various inputs to be put in place promptly and effectively, uniting efficient and high-quality teams and generating cluster advantages (Gemser & Leenders, 2011).

In addition, according to the analysis of SEM results, improving the frequency of TICB, extending the duration of TICB, and promoting the positive role of TICB will affect MCPs. These are other key content to enhance cooperation among technological innovation stakeholders.

6. Conclusions

6.1. Theoretical implications

Guided by TPB, this study focuses on the influencing factors of TICB for MCPs and explores the influencing path and internal mechanism based on SEM. Overall, CA, SCN, PCBC, and CS have a significant favorable influence on CI. CS is added to the TPB to provide a new analytical framework for subsequent studies. This study also deeply analyzed the observational variables affecting CA, SCN, PCBC, CS, CI, and CB and then revealed the internal relationship between factors and indicators, which made the influencing factors more hierarchical and helped researchers further explore different objects.

First, this study expanded the literature on TICB for MCPs based on TPB. It proved that Ajen's theory can be applied to the case of TICB for MCPs and the mediating effect of CA and CI. We extend TPB, which not only considered the influencing factors of TICB for MCPs from the perspective of internal motivation but also introduced CS to explore the role of the external environment. It pointed out the critical influence of CS.

Second, for enterprises, universities, and research institutes, this study constructed an index system to explore a complete framework of influencing factors of the TICB for MCPs, including CA, SCN, PCBC, and CS. The framework identifies the advantages of cooperative behavior governance to incentivize TICB to enhance the subject's initiative. Compared to most research on cooperation in MCPs that adopted the qualitative description method, this study was more systematic and easier to verify. It provided a measuring tool for the behavior and performance of technological innovation stakeholders in cooperation with MCPs and a quantitative guide for future research.

Third, this study used "TPB+SEM" to study the TICB for MCPs, making it more rigorous and scientific. Combined with quantitative analysis, it makes up for the limitation of subjective factors of TPB to a certain extent. It will help to develop more practical solutions, such as interest distribution ratio and risk-sharing mechanism, to form a stable and lasting partnership and enhance openness, inclusiveness, and trust among the leading players.

6.2. Practical implications

This study systematically studies the TICB for MCPs, and the target audiences of the research results include the government, enterprises, universities, and research institutes. Practical significance is mainly reflected in the following four specific recommendations.

6.2.1. Introduce relevant policies and establish high-level innovation cooperation teams

The government can promote the close cooperation of cutting-edge enterprises, universities, and research institutes in the fields related to MCPs through tax incentives, laws, and regulations. For example, we will set up innovation funds and increase investment to encourage enterprises, universities, and research institutes to tackle critical issues and solve bottlenecks in MCPs jointly. The government can promote close cooperation among stakeholders through policy guidance and public services. For example, preferential tax policies can be formulated to reduce enterprises' tax burden and improve their research investment and technological innovation capability. At the same time, public services, such as technology transfer, intellectual property protection, and financing support, can be provided to facilitate and support cooperation among stakeholders. Regulations clearly define the rights and obligations of stakeholders and provide a legal basis for partnerships. It stipulates the cooperation agreement and the rules that competition behavior should follow to avoid the conflicts and losses caused by competition. Coordination mechanisms, communication channels, and decision-making processes will promote cooperative relationships' stable and long-term development.

Technological innovation stakeholders of MCPs to continuously increase talent investment are significant, such as improving salary and providing better career development opportunities. By accumulating high-quality products and services, the high-level team enables the partners to have higher expectations for social exchange and enhance cooperation in more fields. The key to creating a high-level technical innovation cooperation team is to select outstanding talents with an innovative spirit, technical strength, and teamwork spirit. We can attract and select talents with relevant experience and professional skills through recruitment and internal selection. A suitable communication mechanism is the foundation of teamwork. Regular communication channels, such as team meetings and technical exchanges, are necessary to promote communication and collaboration. At the same time, it is necessary to encourage team members to put forward their own opinions and suggestions to stimulate the creativity and innovative spirit of the team. A good team culture and atmosphere is necessary for creating a high-level technical innovation cooperation team.

6.2.2. Define the risk allocation ratio and establish a benefit sharing mechanism

Before determining the proportion of risk allocation, it is necessary to evaluate the partners' technical strength and resource input. This includes assessing technological research and development capabilities, technological achievements, technical personnel, and each party's capital, equipment, time, and other resources investment. We can assess how much technological strength and resource investment impact the risk. The risk tolerance is an essential factor in determining the risk allocation ratio. Some partners may have a high-risk tolerance, while others may have a relatively low-risk tolerance. Through consultation and negotiation, the interests and needs of all parties can be comprehensively considered, and a fair and reasonable proportion of risk allocation can be reached, laying the foundation for the long-term stability of cooperative relations. Through consultation and negotiation, the interests and needs of all parties can be comprehensively considered, and a fair and reasonable proportion of risk allocation can be reached, laying the foundation for the long-term stability of cooperative relations.

A precise benefit sharing mechanism is critical to ensuring the smooth and long-term development of TICB for MCPs. Before the benefit sharing mechanism is developed, the objectives and tasks of cooperation need to be defined. This helps to determine the value and contribution of cooperation and provides a basis for distributing benefits. Formulating a reasonable proportion of distribution is necessary according to the contribution and value. It can be considered according to the proportion of investment, technical difficulty, and market prospects. In the process of TICB, there may be various changes and adjustments. It is necessary to establish a dynamic adjustment mechanism and make timely adjustments to the distribution of benefits according to factors such as the progress of cooperation and market changes. In order to ensure the fairness and rationality of the benefit distribution mechanism, we should establish a monitoring and feedback mechanism, including regular assessment of the cooperative progress and collection of feedback. Through supervision and feedback mechanisms, problems can be found and solved in time to ensure the smooth progress of MCPs.

6.2.3. Establish close cooperation relations and broaden the cooperation network

Close cooperation relations are the key to cooperation for technological innovation stakeholders. Owners must put forward an apparent demand for technological innovation and fully play the coordinating role. On the premise of accurately grasping the status quo of technological innovation, universities and research institutes actively break through the MCPs problem. The survey, design, and construction units provide timely feedback and relevant information and increase the implementation of scientific and technological achievements. They must trust, understand, and respect each other's opinions and positions. We can enhance mutual understanding and trust by strengthening communication and exchanges and laying a good foundation for cooperation. In TICB, the advantages and resources of stakeholders are different, and a reasonable division of labor and cooperation is required. We can realize resource sharing and complementary advantages through the division of labor and cooperation. In order to maintain the partnership, incentives need to be established, including the establishment of incentive funds, the provision of technical support, and the promotion of successful cases.

Through close connection and resource integration, technological innovation stakeholders for MCPs can effectively match external resources with actual demands and form a cooperative network. It is conducive to establishing mutual influence and inextricable internal relations among technological innovation stakeholders. The larger the scale of the cooperative network, the network's total knowledge diversity is conducive to the innovation subject to improve the breadth and heterogeneity of the available knowledge and the efficiency of information transmission among network members.

6.2.4. Build an information integration platform and play a leading role

Enterprises in the industrial chain have a positive attitude towards the stakeholders' honor, abilities, and resources and believe that cooperation with the partners can bring more benefits. The cross-organizational, cross-domain, and cross-regional cooperation of stakeholders in the industrial chain must be associated with constructing an integrated platform. Stakeholders focus on critical risks, integrate research and information technology, promote the combination of new-generation information technology, and create an integrated platform for virtual construction, intelligent construction, and smart management. This platform can provide brighter management and improve the competitiveness of the entire industrial chain. Through the lap bonding service system, technical demonstration promotes the organic combination of technology research and achievement transformation, and cooperative stakeholders with well-off practical experience in key technologies are promoted to realize the landing of special technical services or products.

6.3. Limitations and further direction

Despite the essential findings discussed, this study is also subject to certain limitations that could be addressed in future research. This study discusses the CB for MCPs. Cooperative relationships and cooperative performance deserve systematic consideration. Some studies have pointed out that CB plays a mediate role between cooperative relationships and cooperative performance. Whether this theory can be verified for MCPs remains to be explored. We mentioned in the article that there are differences in technological innovation at different stages, so are there differences in cooperation at different stages? How to set the profit-sharing ratio of the TICB for MCPs? How do we establish a sharing mechanism? These questions still require in-depth consideration.

This study uses SEM to analyze the influencing factors of the TICB for MCPs. SEM has certain advantages in the explanation of the multivariate relationship. However, the causal relationship between variables expressed by SEM relies on cross-sectional data, which can be studied with DEMATEL, interpretive structural model, and other methods. TICB for MCPs is a complicated and dynamic process. It is difficult to predict the future tendency using SEM. Compared with the traditional quantitative methods, system dynamics can not only consider all the influencing factors of CB but also be more suitable for assessing the results of the TICB for MCPs due to its sustainable, systematic, and forward-looking characteristics. In addition, this study was discussed in a specific Chinese institutional context and may not represent all national contexts.

Author contributions

All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Zhenxu Guo. The first draft of the manuscript was written by Zhenxu Guo. Qing'e Wang funded this project.

Funding

The authors gratefully acknowledge the funding support from the National Natural Science Foundation of China (Grant No. 72171237).

Data availability statement

The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of interest

The authors declare no conflict of interest.

References

Adriaanse, A., Voordijk, H., & Dewulf, G. (2010). Adoption and use of interorganizational ICT in a construction project. *Journal of Construction Engineering and Management*, *136*(9), 1003–1014. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000201

Ajzen, I. (2020). The theory of planned behavior: Frequently asked questions. *Human Behavior and Emerging Technologies*, *2*(4), 314–324. https://doi.org/10.1002/hbe2.195

Ajzen, I., & Kruglanski, A. W. (2019). Reasoned action in the service of goal pursuit. *Psychological Review*, *126*(5), 774–786. https://doi.org/10.1037/rev0000155

Aladag, H., & Isik, Z. (2019). Design and construction risks in BOT type mega transportation projects. *Engineering*, *Construction and Architectural Management*, *26*(10), 2223–2242. https://doi.org/10.1108/ECAM-08-2018-0351

Aladag, H., & Isik, Z. (2020). The effect of stakeholder-associated risks in mega-engineering projects: A case study of a PPP airport project. *IEEE Transactions on Engineering Management*, *67*(1), 174–186. https://doi.org/10.1109/TEM.2018.2866269

Ashaduzzaman, M., Jebarajakirthy, C., Weaven, S. K., Maseeh, H. I., Das, M., & Pentecost, R. (2022). Predicting collaborative consumption behaviour: a meta-analytic path analysis on the theory of planned behaviour. *European Journal of Marketing*, *56*(4), 968–1013. https://doi.org/10.1108/EJM-07-2020-0563

Betts, K. R., Hinsz, V. B., & Heimerdinger, S. R. (2011). Predicting intentions of romantic partner abuse with the theory of planned behavior. *Current Psychology*, *30*(2), 130–147. https://doi.org/10.1007/s12144-011-9105-2

Cai, L., Ma, Z., & Li, Z. (2020). Cooperative research and development behavior in technology-based small enterprises: The formation mechanism. *Social Behavior and Personality*, *48*(4), 1–15. https://doi.org/10.2224/sbp.8976

Chen, D., Xiang, P., Jia, F., Zhang, J., & Liu, Z. (2020). An indicator system for evaluating operation and maintenance management of mega infrastructure projects in China. *International Journal of Environmental Research and Public Health*, *17*(24), Article 9589. https://doi.org/10.3390/ijerph17249589

Coenen, L., & Lopez, F. J. D. (2010). Comparing systems approaches to innovation and technological change for sustainable and competitive economies: an explorative study into conceptual commonalities, differences and complementarities. *Journal of Cleaner Production*, *18*(12), 1149–1160. https://doi.org/10.1016/j.jclepro.2010.04.003

Delbufalo, E. (2015). Subjective trust and perceived risk influences on exchange performance in supplier-manufacturer relationships. *Scandinavian Journal of Management*, *31*(1), 84–101. https://doi.org/10.1016/j.scaman.2014.06.002

Dong, R.-R., & Martin, A. (2017). Research on barriers and government driving force in technological innovation of architecture based on BIM. *Eurasia Journal of Mathematics Science and Technology Education*, *13*(8), 5757–5763. https://doi.org/10.12973/eurasia.2017.01025a

Du, F., Bahaddad, A. A., & Kharabsheh, R. (2022). Analysis of enterprise management technology and innovation based on multilinear regression model. *Applied Mathematics and Nonlinear Sciences*, *7*(2), 523–532. https://doi.org/10.2478/AMNS.2021.1.00078

Flyvbjerg, B. (2014). What you should know about megaprojects and why: An overview. *Project Management Journal*, *45*(2), 6–19. https://doi.org/10.1002/pmj.21409

Gemser, G., & Leenders, M. A. A. M. (2011). Managing cross-functional cooperation for new product development success. *Long Range Planning*, *44*(1), 26–41. https://doi.org/10.1016/j.lrp.2010.11.001

Hagger, M. S., Chan, D. K. C., Protogerou, C., & Chatzisarantis, N. L. D. (2016). Usingmeta-analytic path analysis to test theoretical predictions in health behavior: An illustration based on meta-analyses of the theory of planned behavior. *Preventive Medicine*, *89*, 154–161. https://doi.org/10.1016/j.ypmed.2016.05.020

Hair, J. F., Sarstedt, M., Ringle, C. M., & Mena, J. A. (2012). An assessment of the use of partial least squares structural equation modeling in marketing research. *Journal of the Academy of Marketing Science*, *40*(3), 414–433. https://doi.org/10.1007/s11747-011-0261-6

Hau, Y. S., & Kim, Y.-G. (2011). Why would online garners share their innovation-conducive knowledge in the online game user community? Integrating individual motivations and social capital perspectives. *Computers in Human Behavior*, *27*(2), 956–970. https://doi.org/10.1016/j.chb.2010.11.022

Helm, R., & Kloyer, M. (2004). Controlling contractual exchange risks in R&D interfirm cooperation: an empirical study. *Research Policy*, *33*(8), 1103–1122. https://doi.org/10.1016/j.respol.2004.05.003

Hu, R., & Diao, X. (2021). Exploring the open innovation information spillover effect: conceptual framework construction and exploratory analysis. *IEEE Access*, *9*, 93734–93744. https://doi.org/10.1109/ACCESS.2021.3093322

Huang, L., Li, Y., Huang, X., & Zhou, L. (2021). How social distance affects the intention and behavior of collaborative consumption: A study based on online car-hailing service. *Journal of Retailing and Consumer Services*, *61*, Article 102534. https://doi.org/10.1016/j.jretconser.2021.102534

Jain, S., Singhal, S., Jain, N. K., & Bhaskar, K. (2020). Construction and demolition waste recycling: Investigating the role of theory of planned behavior, institutional pressures and environmental consciousness. *Journal of Cleaner Production*, *263*, Article 121405. https://doi.org/10.1016/j.jclepro.2020.121405

Johnson, S. E., & Hall, A. (2005). The prediction of safe lifting behavior: An application of the theory of planned behavior. *Journal of Safety Research*, *36*(1), 63–73. https://doi.org/10.1016/j.jsr.2004.12.004

Jones, S. L., Leiponen, A., & Vasudeva, G. (2021). The evolution of cooperation in the face of conflict: Evidence from the innovation ecosystem for mobile telecom standards development. *Strategic Management Journal*, *42*(4), 710–740. https://doi.org/10.1002/smj.3244

Lee, S. J., & Kim, H. L. (2018). Roles of perceived behavioral control and self-efficacy to volunteer tourists' intended participation via theory of planned behavior. *International Journal of Tourism Research*, *20*(2), 182–190. https://doi.org/10.1002/jtr.2171

Li, C., & Wang, S. (2022). Digital optimization, green R&D collaboration, and green technological innovation in manufacturing enterprises. *Sustainability*, *14*(19), Article 12106. https://doi.org/10.3390/su141912106

Li, J., Zuo, J., Cai, H., & Zillante, G. (2018). Construction waste reduction behavior of contractor employees: An extended theory of planned behavior model approach. *Journal of Cleaner Production*, *172*, 1399–1408. https://doi.org/10.1016/j.jclepro.2017.10.138

Liao, Z., & Long, S. (2019). Can interfirm trust improve firms' cooperation on environmental innovation? The moderating role of environmental hostility. *Business Strategy and the Environment*, *28*(1), 198–205. https://doi.org/10.1002/bse.2249

Liu, J., & Ma, G. (2021). Study on incentive and supervision mechanisms of technological innovation in megaprojects based on the principal-agent theory. *Engineering*, *Construction and Architectural Management*, *28*(6), 1593–1614. https://doi.org/10.1108/ECAM-03-2020-0163

Long, X., Chen, Y., Du, J., Oh, K., Han, I., & Yan, J. (2017). The effect of environmental innovation behavior on economic and environmental performance of 182 Chinese firms. *Journal of Cleaner Production*, *166*, 1274–1282. https://doi.org/10.1016/j.jclepro.2017.08.070

Neto, I. L., Matsunaga, L. H., Machado, C. C., Gunther, H., Hillesheim, D., Pimentel, C. E., Vargas, J. C., & D'Orsi, E. (2020). Psychological determinants of walking in a Brazilian sample: An application of the theory of planned behavior. *Transportation Research Part F: Traffic Psychology and Behaviour*, *73*, 391–398. https://doi.org/10.1016/j.trf.2020.07.002

Ma, C.-A., Xiao, R., Chang, H.-Y., & Song, G.-R. (2022). Founder management and innovation: An empirical analysis based on the theory of planned behavior and fuzzy-set qualitative comparative analysis. *Frontiers In Psychology*, *13*, Article 827448. https://doi.org/10.3389/fpsyg.2022.827448

Ma, L., & Fu, H. (2020). Exploring the influence of project complexity on the mega construction project success: a qualitative comparative analysis (QCA) method. *Engineering*, *Construction and Architectural Management*, *27*(9), 2429–2449. https://doi.org/10.1108/ECAM-12-2019-0679

Nieto, J. M., & Santamaria, L. (2010). Technological collaboration: Bridging the innovation gap between small and large firms.

Journal of Small Business Management, *48*(1), 44–69. https://doi.org/10.1111/j.1540-627X.2009.00286.x

Noktehdan, M., Shahbazpour, M., Zare, M. R., & Wilkinson, S. (2019). Innovation management and construction phases in infrastructure projects. *Journal of Construction Engineering and Management*, *145*(2), Article 04018135. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001608

Ozorhon, B. (2013). Response of construction clients to low-carbon building regulations. *Journal of Construction Engineering and Management*, *139*(12), Article A5013001. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000768

Peng, L., & Chan, A. H. S. (2019). Exerting explanatory accounts of safety behavior of older construction workers within the theory of planned behavior. *International Journal of Environmental Research and Public Health*, *16*(18), Article 3342. https://doi.org/10.3390/ijerph16183342

Scuotto, V., Beatrice, O., Valentina, C., Nicotra, M., Di Gioia, L., & Briamonte, M. F. (2020). Uncovering the micro-foundations of knowledge sharing in open innovation partnerships: An intention-based perspective of technology transfer. *Technological Forecasting and Social Change*, *152*, Article 119906. https://doi.org/10.1016/j.techfore.2019.119906

Segarra-Cipres, M., Roca-Puig, V., & Carlos Bou-Llusar, J. (2014). External knowledge acquisition and innovation output: an analysis of the moderating effect of internal knowledge transfer. *Knowledge Management Research* & *Practice*, *12*(2), 203–214. https://doi.org/10.1057/kmrp.2012.55

Sendstad, L. H., Chronopoulos, M., & Hagspiel, V. (2023). Optimal risk adoption and capacity investment in technological innovations. *IEEE Transactions on Engineering Management*, *40*(2), 576–589. https://doi.org/10.1109/TEM.2021.3056142

Shou, Y., Shan, X., Dai, J., Xu, D., & Che, W. (2023). Actions speak louder than words? The impact of subjective norms in the supply chain on green innovation. *International Journal of Operations* & *Production Management*, *43*(6), 879–898. https://doi.org/10.1108/IJOPM-04-2022-0265

Shukra, Z. A., Zhou, Y., & Wang, L. (2021). An adaptable conceptual model for construction technology transfer: The BRI in Africa, the case of Ethiopia. *Sustainability*, *13*(6), Article 3376. https://doi.org/10.3390/su13063376

Sparrevik, M., Wangen, H. F., Fet, A. M., & De Boer, L. (2018). Green public procurement - A case study of an innovative building project in Norway. *Journal of Cleaner Production*, *188*, 879–887. https://doi.org/10.1016/j.jclepro.2018.04.048

Sun, J., & Zhang, P. (2011). Owner organization design for mega industrial construction projects. *International Journal of Project Management*, *29*(7), 828–833. https://doi.org/10.1016/j.ijproman.2011.04.005

Wang, Y., Shen, C., Zuo, J., & Rameezdeen, R. (2021). Same tune, different songs? Understanding public acceptance of mega construction projects: A comparative case study. *Habitat International*, *118*, Article 102461. https://doi.org/10.1016/j.habitatint.2021.102461

Xiong, C., Chang, V., Scuotto, V., Shi, Y., & Paoloni, N. (2021). The social-psychological approach in understanding knowledge hiding within international R&D teams: An inductive analysis. *Journal of Business Research*, *128*, 799–811. https://doi.org/10.1016/j.jbusres.2019.04.009

Yan, L., Guo, L., & Ning, Y. (2020). Understanding construction contractors' intention to undertake consummate performance behaviors in construction projects. *Advances in Civil Engineering*, *2020*, Article 3935843. https://doi.org/10.1155/2020/3935843

Yang, R., Yue, C., Li, J., Zhu, J., Chen, H., & Wei, J. (2020). The influence of information intervention cognition on college students' energy-saving behavior intentions. *International Journal of Environmental Research and Public Health*, *17*(5), Article 1659. https://doi.org/10.3390/ijerph17051659

Yi, H., & Zhang, Q. (2022). Knowledge-sharing strategies of university-industry alliances promoting green technology innovation in ecosystems: Based on the utility of multichannel funding. *IEEE Access*, *10*, 65728–65743. https://doi.org/10.1109/ACCESS.2022.3184422

Yuan, H., Wu, H., & Zuo, J. (2018). Understanding factors influencing project managers' behavioral intentions to reduce waste in construction projects. *Journal of Management in Engineering*, *34*(6), Article 04018031. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000642

Zaman, U., Florez-Perez, L., Anjam, M., Khwaja, M. G., & Ul-Huda, N. (2022). At the end of the world, turn left: examining toxic leadership, team silence and success in mega construction projects. *Engineering, Construction and Architectural Management*, *30*(6), 2436–2462. https://doi.org/10.1108/ECAM-08-2021-0755

Zhang, G., & Tang, C. (2017). How could firm's internal R & D collaboration bring more innovation?. *Technological Forecasting and Social Change*, *125*, 299–308. https://doi.org/10.1016/j.techfore.2017.07.007

Zhang, Y., Wang, Y., & Yao, H. (2022). How does the embeddedness of relational behaviours in contractual relations influence inter-organisational trust in construction projects? *Engineering, Construction and Architectural Management*, *29*(1), 222–244. https://doi.org/10.1108/ECAM-07-2020-0557

Zhao, S., Yu, H., Xu, Y., & Bi, Z. (2014). Relationship-specific investment, value creation, and value appropriation in cooperative innovation. *Information Technology* & *Management*, *15*(2), 119–130. https://doi.org/10.1007/s10799-014-0174-4

Zhao, L., Mbachu, J., & Liu, Z. (2022). Developing an integrated BIM plus GIS web-based platform for a mega construction project. *KSCE Journal of Civil Engineering*, *26*(4), 1505–1521. https://doi.org/10.1007/s12205-022-0251-x

Zheng, X., Lu, Y., Le, Y., Li, Y., & Fang, J. (2018). Formation of interorganizational relational behavior in megaprojects: Perspective of the extended theory of planned behavior. *Journal of Management In Engineering*, *34*(1), Article 04017052. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000560

Zhu, J., Fang, M., Shi, Q., Wang, P., & Li, Q. (2018). Contractor cooperation mechanism and evolution of the green supply chain in mega projects. *Sustainability*, *10*(11), Article 4306. https://doi.org/10.3390/su10114306

Zhu, J., Hertogh, M., Zhang, J., Shi, Q., & Sheng, Z. (2020). Incentive mechanisms in mega project-risk management considering owner and insurance company as principals. *Journal of Construction Engineering and Management*, *146*(10), Article 04020120. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001915

Zhu, S., Hagedoorn, J., Zhang, S., & Liu, F. (2021). Effects of technological distance on innovation performance under heterogeneous technological orientations. *Technovation*, *106*, Article 102301. https://doi.org/10.1016/j.technovation.2021.102301

APPENDIX

Section 1: Corporate and Personal Information

(Please state or tick the appropriate answer):

1. What is your role in the mega construction project?

☐ Owner ☐ Contractor

☐ Universities & research institute ☐ Other

2. How long have you worked?

☐ 1–3 years ☐ 4–7 years ☐ > 8 years

3. What is your job category?

☐ Senior management ☐ Ordinary management ☐ Technical personnel

4. What is your education background?

☐ Bachelor ☐ Postgraduate ☐ Other

Section 2: Influencing factors of mega construction project technological innovation cooperation

Please indicate to what extent your project, has introduced mega construction project technological innovation cooperation in the following aspects. Kindly use the scale from 1 to 5; where **1** denotes *Very Unimportant*, **2** denotes *Unimportant*, **3** denotes *Average*, **4** denotes *Important* and **5** denotes *Very Important*. Kindly write the appropriate number in the last column ***Your response*** for each statement.

	Very Unimportant 1 Unimportant 2 Average 3 Important 4 Very Important 5	Your response
1	We are delighted with both formal and informal cooperation.	1
2	We trust each other to take a positive attitude in responding to demand and supply.	1
3	We believe cooperation among innovation subjects can achieve the expected benefits.	1
4	The attitude of the whole industry to participate in mega construction project technological innovation cooperation is positive.	1
5	Other enterprises recognize the cooperative behavior of innovation subjects.	1
6	From the perspective of their practical development, innovation cooperation is essential.	1
7	We can undertake the task of technological innovation cooperation in mega construction projects.	1
8	We can perceive the risk of mega construction project technological innovation.	1
9	We can solve the potential problems caused by the schedule pressure of mega construction projects through technological innovation cooperation.	1
10	We are ready to cooperate actively.	1
11	We are willing to provide the resources needed for cooperation on technological innovation in mega construction projects.	1
12	We are willing to actively promote establishing an efficient and open cooperation ecosystem for technological innovation in mega construction projects.	1
13	We are willing to continue to carry out technological innovation cooperation in mega construction projects.	1
14	We believe that policy support can enhance the willingness of major parties to cooperate.	1
15	We believe that economic input is necessary for technological innovation cooperation in mega construction projects.	1
16	We believe that talent investment can promote innovation cooperation among subjects.	1
17	We believe that technical support is the foundation of collaborative interaction.	1
18	Innovation subjects are actively building cooperation networks.	1
19	Innovation subjects increase the frequency of cooperation.	1
20	Innovation subjects strive to extend technological innovation cooperation time.	1

Section 3: Openning Questions

What are the most critical constraints for mega construction project technological innovation cooperation? Do you have any good suggestions to promote the innovation enthusiasm of the participating units and most builders?