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Exploring environmentally responsible behavior of megaproject contractors using an extended theory of planned behavior

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Environmentally responsible behavior (ERB) of contractors in megaprojects is crucial for promoting sustainability, but how to trigger and predict it remains unclear. This study integrates moral identity and corporate green culture into the theory of planned behavior (TPB) to develop an extended TPB (ETPB). Based on a questionnaire survey (N = 181) from Chinese megaprojects, we found that (1) contractors' attitudes, subjective norms, and perceived behavioral control positively influence their intentions to engage in ERB; (2) perceived behavioral control, intentions, moral identity, and corporate green culture positively influence ERB; and (3) the explanatory power (R^2) and predictive power ($PLS_{predict}$, CVPAT) of the ETPB model are superior to those of the TPB model. These findings offer novel theoretical insights through the ETPB model in the context of megaprojects and provide practical guidance for promoting ERB among contractors.

Keywords Megaproject contractors, Environmentally responsible behavior, Extended theory of planned behavior, Moral identity, Corporate green culture

Despite the economic benefits brought about by economic globalization and global urbanization, they have also led to environmental sustainability issues[1,2]. In the face of this pressing challenge, it is imperative that we adopt various environmentally responsible actions[3], referred to as environmentally responsible behavior (ERB). In the field of construction engineering, megaprojects are characterized by their extensive scale, substantial investment, prolonged construction periods, and high level of technical complexity[4,5]. These projects, such as China's Hong Kong-Zhuhai-Macao Bridge and Australia's Sydney Metro, profoundly impact both national welfare and people's livelihoods[6]. The construction of megaprojects has led to significant alterations in the natural environment at construction sites[7], which have profoundly affected the surrounding ecology[8]. Additionally, such projects have faced frequent criticism due to their high levels of resource consumption as well as their tendency to generate substantial construction waste and significant carbon emissions[9–11]. Consequently, the environmental impacts of megaproject construction constitute a significant area of concern[8]. For example, the construction of the Wudongde Hydropower Station in China offers substantial clean energy benefits. However, this project has continually attracted societal attention and comprehensive evaluations as a result of its environmental impacts[12]. As core actors involved in the construction process, megaproject contractors play a crucial role in environmental protection[13]. The ERB exhibited by contractors directly impacts the environmental performance and sustainability of construction projects[14]. Therefore, it is imperative to ensure that contractors working on megaprojects engage in ERB to promote effective environmental governance and sustainable development.

However, in the context of construction projects, particularly megaprojects, comprehensive and in-depth studies on the ERB of contractors remain scarce. Fragmented research has mainly applied various theories—such as institutional theory[15], game theory[16], stakeholder theory[17], fraud triangle theory[18], the contagion effect[13], and the theory of planned behavior[14]—to explain and predict the ERB of megaproject contractors. Notably, the Theory of Planned Behavior (TPB) is one of the most widely discussed theories in behavioral research[19].

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However, due to the complexity and multidimensionality of ERB, the explanatory and predictive power of the TPB is limited[20]. In the context of megaprojects, research on the ERB of contractors has not discussed or extended the TPB sufficiently. Moral and green cultural factors often play significant roles in promoting ERB[21,22]. However, few studies have incorporated these essential factors into the TPB framework. Therefore, this study proposes an extended TPB (ETPB) model by introducing two additional variables (moral identity and corporate green culture) into the TPB model. This expansion of the TPB aims to improve researchers' ability to explain and predict the ERB of megaproject contractors comprehensively. Accordingly, this study seeks to address the following questions:

RQ1: Does do moral identity and corporate green culture influence the ERB of megaproject contractors?
RQ2: Does the ETPB (i.e., a version of the TPB to which the variables of moral identity and corporate green culture have been added) explain and predict the ERB of megaproject contractors?
RQ3: If the ETPB is sufficiently explanatory and predictive, how does it compare to the TPB in terms of its ability to explain and predict the ERB of megaproject contractors?

To address these questions, this study integrated moral identity and corporate green culture into the TPB, thereby developing an ETPB model. This study conducted an empirical investigation targeting megaproject contractors in China. Ultimately, 181 valid questionnaires were collected, and partial least squares structural equation modeling (PLS-SEM) was used for empirical testing. This study enriches the scope of the ETPB in the field of megaprojects and provides insights into ways of promoting proactive ERB among megaproject contractors.

The remainder of this study is organized as follows. "Theoretical analysis and research hypotheses" analyzes the relevant theory and proposes corresponding research hypotheses. "Method" introduces the research methodology. "Results" presents the findings of this study. "Discussion" provides a detailed discussion of the results, theoretical contributions, and practical implications. Finally, "Conclusion" concludes the study, analyzes its limitations, and highlights directions for future research.

Theoretical analysis and research hypotheses

Environmentally responsible behavior in contractors within megaprojects

The definition of megaprojects remains controversial. Existing definitions emphasize different aspects of this notion. For instance, Flyvbjerg (2014) and Fu et al. (2023) suggested that megaprojects involve investments of one billion US dollars or more[4,13]. Van Marrewijk et al. (2008) and Wang et al. (2021) emphasized the fact that megaprojects are initiated and funded primarily by governments[5,23]. The question of which decision is best has no right or wrong answer; rather, the optimal definition depends primarily on the specific research context under investigation. In light of the conditions in China, this study defines megaprojects as large and complex engineering projects that are initiated and funded primarily by the government, which have significant impacts on politics, the economy, society, and the environment.

As mentioned, environmentally responsible behavior (ERB) involves a series of actions on the part of agents who aim to take responsibility for the environment. For contractors, these actions include, but are not limited to:(1) investing in and developing green construction technologies; (2) using environmentally friendly construction techniques, equipment, building materials, and clean energy during the construction process; and (3) implementing measures to handle construction waste, wastewater, and emissions properly[13,24]. A prominent aspect of megaprojects is the fact that they have significant impacts, including on the ecological environment. Throughout the construction process, contractors are responsible for the core tasks involved in the project at hand and operate as implementers and builders[13]. Therefore, to reduce the ecological impacts of megaprojects, it is essential to focus first on the ERB of contractors. Previous scholars have recognized the importance of the ERB of contractors and have conducted some research to investigate this topic. However, these studies have had certain limitations. For example, Xie et al. (2022) focused only on the TPB itself in their study of megaproject ERB[14]. Their study did not attempt to use the ETPB to explain and predict this behavior more effectively. Nevertheless, extensive empirical research has indicated that studies based on the TPB should consider the incorporation of additional variables with the goal of enhancing the explanatory and predictive power of this theory[19]. Regrettably, in the context of megaprojects, the possibility of using the ETPB to explain and predict contractors' ERB seems to have been overlooked.

Theory of planned behavior

The theory of planned behavior (TPB) is a social psychological theory developed by Ajzen (1991) to explain and predict people's intentions or behaviors[25]. The TPB extends the theory of reasoned action by incorporating the notion of perceived behavioral control. According to the TPB, attitudes, subjective norms, and perceived behavioral control are direct antecedents of intention[25]. Both intentions and perceived behavioral control influence behavior[25]. The TPB is considered to constitute a powerful tool with regard to explaining behaviors, including ERB[26].

According to previous research, the TPB is not limited to the study of individual behaviors. Researchers have also confirmed that the TPB exhibits sufficient explanatory and predictive power to be employed in organizational behavior research, particularly with respect to the study of ERB. For instance, scholars have used the TPB to explore household energy-saving behaviors[27], corporate circular economy practices[28], corporate environmental innovation behaviors[29], and megaproject ERB[14]. Therefore, it is appropriate to apply the TPB to study the ERB of contractors in the context of megaprojects.

Attitudes and intentions

Attitude, as defined by Ajzen (1991), refers to people's positive or negative evaluations and expectations concerning the outcomes of a given behavior[25]. In this study, attitude represents contractors' perceptions and evaluations of ERB. If contractors believe that implementing ERB is likely to lead to desirable outcomes—such as increased competitiveness, additional environmental benefits, a reduced risk of penalties, and an improved corporate image—they attend to adopt positive attitudes toward this behavior[30]. Gao et al. (2023) revealed that when contractors adopt positive attitudes towards low-carbon behavior, their intentions to engage in this behavior are activated[31]. Similarly, Wu et al. (2017) confirmed that attitude facilitates intentions in a study on contractors' behavior in the context of construction and demolition waste management[24]. Therefore, the following hypothesis is proposed in this study:

H1(+) Attitudes positively influences contractors' intentions to engage in ERB.

Subjective norms and intentions

Subjective norms refer to the perceptions of significant others or organizations regarding people's attitudes toward and opinions of the possibility of performing a specific behavior[24]. Essentially, subjective norms reflect external social norms or expected pressures[26]. When organizations perceive a strong societal expectation to perform a certain behavior, subjective norms enhance their intentions to carry out that behavior[24]. In megaprojects, contractors often face environmental expectations from stakeholders such as governments, industry associations, and social media[17]. Xie et al. (2022) found that in the context of megaproject construction, the more strongly actors perceive stakeholders to expect them to implement ERB, the stronger their intentions are[14]. Therefore, the stronger the subjective norms perceived by contractors are, the more likely their intentions for ERB will be activated. Therefore, the following hypothesis is proposed in this study:

H2(+): Subjective norms positively influence contractors intentio n s to engage in ERB.

Perceived behavioral control and intention/ERB

Perceived behavioral control refers to the perceived ease or difficulty of a specific behavior as well as the perceived controllability of that behavior[25]. It reflects confidence in one's ability to perform a given behavior. Generally, if individuals or organizations believe that they have the necessary capabilities to perform a behavior easily, their intentions are strengthened[26]. For instance, when project managers perceive they have strong control over the actions that can be taken to reduce construction waste, their intentions to engage in such actions tend to be stronger[32]. Perceived behavioral control can also facilitate the actual performance of a behavior directly[25]. Khan et al. (2020) confirmed that an organization's perceived behavioral control not only stimulates actors' intentions but also directly drive their ultimate behaviors[33]. Xie et al. (2022) also affirmed that perceived behavioral control is a direct antecedent of relevant actors' intentions and behaviors regarding megaproject ERB[14]. Therefore, the following hypothesis is proposed in this study:

H3(+): Perceived behavioral control positively influences contractors' intentions to engage in ERB.

H4(+): Perceived behavioral control positively influences contractors' ERB.

Intention and ERB

Intention refers to people's intrinsic motivation and willingness to perform a specific behavior. The TPB posits that intentions directly drive the implementation of behavior[26]. The stronger the intentions are, the more likely the behavior will be performed[31]. Khan et al. (2023) demonstrated that intentions constitute a significant predictor of behavior in a study on corporate circular economy practices[28]. Jain et al. (2020) also confirmed the ability of intentions to promote behavior in a study on contractors' behavior regarding the recycling of construction and demolition waste[34]. In this study, intentions refer to contractors' willingness to implement ERB. Only if contractors genuinely intend to implement ERB will they actually exhibit such behavior. Therefore, the following hypothesis is proposed in this study:

H5(+): Intentions positively influence contractors' ERB.

The extended theory of planned behavior

Although the efficacy of the TPB has been well established, some scholars have suggested that its explanatory and predictive capabilities can still be enhanced[19]. Ajzen (2020) agrees that it is appropriate to add other reasonable external variables to the TPB[26]. In empirical research on ERB, many scholars have introduced new predictive factors into the TPB model with the goal of improving researchers' ability to explain and predict intentions and behaviors, e.g., Wang et al.[35], Jia et al.[36], Wang et al.[37], Gao and Tang[38]. This approach aligns with the evolving nature of the model, which aims to adapt and integrate broader influences that affect behavioral outcomes in specific contexts.

Attitudes, subjective norms, and perceived behavioral control are the core predictive variables include in the TPB[25]. Specifically, attitudes reflect the individual's evaluation of the consequences of the behavior; subjective norms emphasize others' perceptions and influence regarding the behavior; and perceived behavioral control represents the individual's sense of control over performing the behavior[25,39]. Notably, the concept of subjective norms within the TPB primarily focuses on "how others expect one to behave," and thus reflects external social norms[26]. However, as a form of moral, civic, and prosocial behavior, ERB is more likely to be influenced by internal normative factors within individuals or organizations. These factors include intrinsic values, beliefs,

and moral standards. Compared with external social norms, internal norms place greater emphasis on "how one expects oneself to behave." Unfortunately, TPB overlooks the role of these internally driven normative factors, which are fundamentally rooted in moral motivation and value orientation.

To address this limitation, similar studies have often considered the possible introduction of variables related to moral factors[19]. Among these moral factors, moral identity has emerged as a key moral construct and has been integrated into the TPB model in numerous studies[40–43]. Moral identity refers to the extent to which individuals internalize moral traits as part of their self-concept and regard them as central components of their identity[44]. When individuals' self-perception is closely aligned with their moral beliefs, they are more likely to use these internalized moral values as a basis for guiding their behavioral choices[45]. Existing studies have demonstrated that moral identity has a direct positive impact on moral decision-making[45] and is significantly positively associated with prosocial behavior[46].

In addition to moral motivation, green cultural value orientation represents another important form of internal normative constraint that plays a critical role in shaping ERB. Corporate green culture refers to a cultural paradigm that integrates the principles of environmental protection and sustainable development into an organization's values, beliefs, behavioral norms, and practical activities[47]. Such a culture contributes to shaping a collective value orientation centered on environmental protection. This shared value fosters stronger identification with, and more active engagement in, ERB among organizations and their members[48]. Relevant studies have shown that corporate green culture can directly promote organizational members' active engagement in ERB[49]. In addition, corporate green culture also contributes to advancing environmental responsibility practices within the organization[50]. Although the incorporation of this variable into extensions of the TPB remains relatively limited, its potential to enhance ERB and address the theory's limitations should not be overlooked.

To enhance both the explanatory and predictive power of the TPB, this study introduces moral identity and corporate green culture as direct antecedents of ERB. These additions form the foundation of an extended TPB (ETPB) model specifically developed for this study.

Moral identity and ERB

Moral identity refers to the extent to which an individual views moral standards as a core component of themselves that can reflect their self-perceptions and value judgments in response to moral issues[44]. Moral identity has frequently been identified as a crucial antecedent that should not be ignored when seeking to predict moral behavior[51]. Luan et al. (2023) conducted a meta-analysis that emphasized the fact that moral identity can effectively explain moral behavior[21]. Numerous studies have confirmed that moral identity can actively promote moral behavior[52–55]. In this study, moral behavior refers to contractors' ERB. Organizational members who exhibit a strong moral identity may view environmental protection as their moral duty. Therefore, they may support contractors' ERB by engaging in such actions themselves or by advising and contributing ideas to their organization. Accordingly, this study posits that moral identity has a direct positive influence on contractors' implementation of ERB. Based on the above analysis, the following hypothesis is proposed:

H6(+): Moral identity positively influences contractors' ERB.

Corporate green culture and ERB

Corporate green culture is a crucial component of organizational culture that is defined as a set of core values and internal behavioral norms with an emphasis on environmental protection[56]. Organizational culture theory suggests that organizational culture can influence the behaviors of an organization and its members[57]. Corporate green culture serves as a key motivator of ERB. Khaddage-Soboh et al. (2024) highlighted the significant role that organizational green culture plays in promoting green practices and enhancing environmental performance[58]. Hooi et al. (2022) reported that a green culture positively influences green organizational citizenship behaviors[22]. Azhar and Yang (2022) also confirmed that green culture can foster pro-environmental behaviors in the workplace to some extent[59]. Under the influence of corporate green culture, contractors' sense of environmental responsibility is likely to increase. Such an increase can reduce environmentally irresponsible behaviors. Accordingly, this study posits that corporate green culture has a direct positive influence on contractors' implementation of ERB. Based on the above analysis, the following hypothesis is proposed:

H7(+): Corporate green culture positively influences contractors' ERB.

On the basis of the preceding discussion and hypotheses, the research model for this study was constructed, as illustrated in Fig. 1.

Method

Questionnaire design

Questionnaire surveys are the most popular method in empirical research on ERB. The simplicity of this approach, alongside the effectiveness and reliability of data collection that it offers, has been extensively validated in numerous empirical studies[13,14,35]. Therefore, similar to previous studies, this study collected data by conducting a questionnaire survey. Before conducting the formal survey, we designed a questionnaire with scientific rigor. It consists of three parts: (1) an introduction, which includes details regarding the surveying entity as well as the background and purpose of the research alongside relevant instructions; (2) a section collecting the demographic information of the respondents; and (3) measurement items pertaining to all latent variables included in the research model. This study measures respondents' attitudes using a 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree). All latent variables' measurements

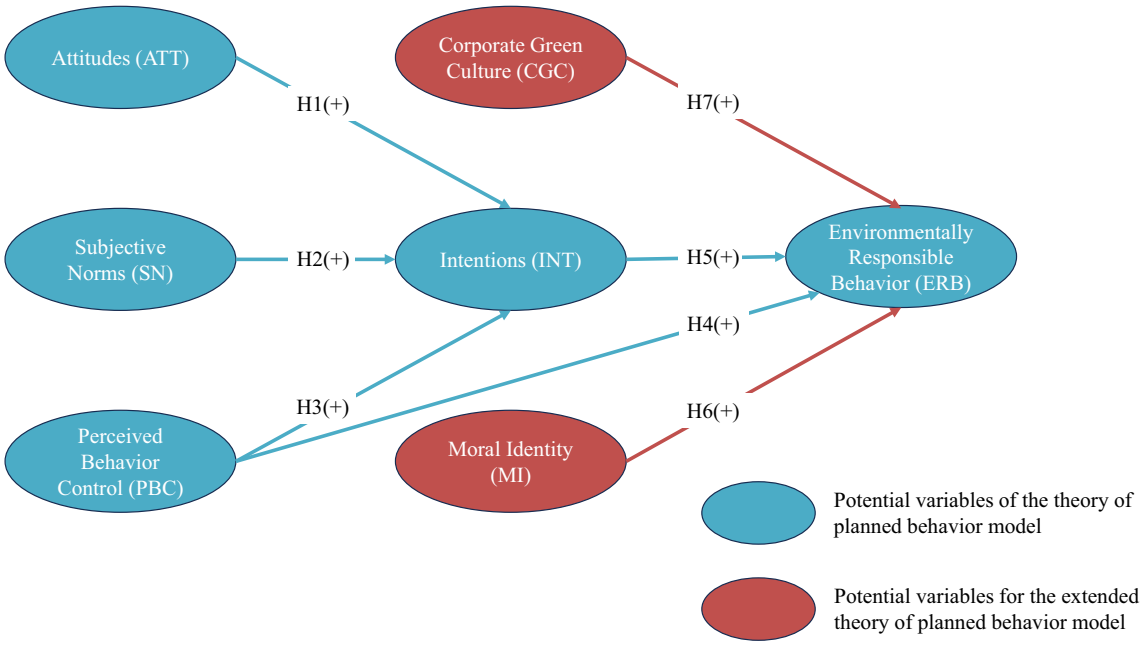

Fig. 1. Research model and hypotheses.

in this study are derived from scales that have been validated in previous research. Additionally, to adapt the measurement items to the context of megaprojects, these items have been appropriately modified to improve their accuracy and applicability.

The measurement of attitudes is drawn primarily from Wu et al. (2017)[24] and includes five items. The measurements used for subjective norms and perceived behavioral control are mainly derived from the studies conducted by Zheng et al.[60] and Wu et al. (2017)[24]; each measurement consists of five items. The measurement of intentions is primarily drawn from Zheng et al.[60] and includes three items. The measurement of ERB is derived primarily from Wu et al.[24] and Zhu and Sarkis[61] and includes twelve items. The measurement of moral identity is drawn primarily from Aquino and Reed (2002)[44] and includes two dimensions: internalization and symbolization. Compared to symbolization, internalization often provides a better explanation and prediction of ERB[51]. Therefore, this study ultimately employed five items drawn from the internalization dimension, including two reverse-coded items, i.e., MI1 and MI2 (which were reverse-coded during the formal analysis). Prior to identifying these measurement items, this study followed the suggestions of Aquino and Reed (2002), who identified nine moral qualities (caring, compassionate, fair, friendly, generous, helpful, hardworking, honest, and kind) and asked respondents to imagine a person with these good moral qualities before responding to the measurement items[44]. The measurement of corporate green culture is primarily drawn from Banerjee[62] and Fraj et al.[56], and includes six items.

Given that the measurement scales referenced in this study were originally written in English, the study employed a translation process to minimize language-related biases resulting from the differences between English and Chinese. Three bilingual professionals implemented this process. The first of these professionals was responsible for translating the English versions of the scales into Chinese. The second professional translated the Chinese version back into English. The third professional then compared this English translation with the original English version to ensure consistency. The comparison revealed no significant differences, thus indicating that the translation process was implemented effectively. Before the questionnaire was officially distributed, a pilot test was conducted. The researchers invited six experts, including three practitioners and three senior scholars working in the field of megaprojects, to assess the questionnaire. These experts assessed the content and structure of the questionnaire with the goal of ensuring its comprehensibility, validity, and accuracy. Based on the feedback provided by these experts, the research team engaged in in-depth discussions and made multiple revisions to the questionnaire, after which the final version was ultimately produced. Detailed information regarding the measurement items included in each part of the final scale and their sources is presented in Table 1.

Participants and procedure

As the world's largest developing country, China is responsible for the highest number of megaprojects worldwide[6]. These megaprojects have also led to severe ecological and environmental issues that have attracted international attention. Additionally, due to the advancement of the Belt and Road Initiative, China has been involved in numerous international megaprojects. Therefore, empirical data concerning Chinese megaproject contractors are significantly representative at the global level. Before the formal survey was conducted, the minimum sample size required was estimated. Initially, with the assistance of G*Power 3.1, the minimum sample size was calculated to be 85 (see Fig. 2)[63]. When the more stringent inverse square root method recommended by Kock and Hadaya (2018) was employed, the minimum sample size was determined to be 160[64].

Latent variable	Measurement items	Key source(s)
Attitudes (ATT)	ATT1: Implementing ERB can improve environmental quality	24
	ATT2: Implementing ERB can promote the sustainable development of engineering projects	
	ATT3: Implementing ERB can enhance environmental benefits	
	ATT4: Implementing ERB can enhance one's social image	
	ATT5: The implementation of ERB is worthy of promotion	
Subjective norms (SN)	SN1: Competitors in the same industry are actively implementing ERB	24,60
	SN2: Owners wish to promote ERB	
	SN3: The government aims to promote ERB	
	SN4: Industry associations believe that ERB should be implemented	
	SN5: Social media platforms constantly monitor the implementation of ERB	
Perceived behavioral control (PBC)	PBC1: Having sufficient technical capabilities to implement ERB	24,60
	PBC2: Having sufficient managerial capabilities to implement ERB	
	PBC3: Having sufficient resources to implement ERB	
	PBC4: Having sufficient experience in implementing ERB	
	PBC5: Having sufficient confidence to implement ERB	
Intentions (INT)	INT1: Intending to implement ERB now	60
	INT2: Intending to implement ERB in the future	
	INT3: Intending to consistently implement ERB	
Moral identity (MI)	MI1: I would be ashamed to be a person who exhibits these characteristics	44
	MI2: Exhibiting these characteristics is not really important to me	
	MI3: It would make me feel good to be a person who exhibits these characteristics	
	MI4: Being someone who exhibits these characteristics is an important part of who I am	
	MI5: I strongly desire to have these characteristics	
Corporate green culture (CGC)	CGC1: Ensuring that each member understands the importance of environmental protection through collective efforts	56,62
	CGC2: Establishing clear rules and regulations to encourage environmental awareness across all aspects	
	CGC3: Striving to minimize the adverse environmental impacts of the construction process with regard to contracted projects	
	CGC4: The core values emphasize environmental protection	
	CGC5: Linking environmental objectives with other corporate goals	
	CGC6: Actively engaging in construction technology innovation to minimize environmental impact	
Environmentally responsible behavior (ERB)	ERB1: Research and development expenditures related to green construction technologies account for a significant portion of total operating expenses	24,61
	ERB2: The proportion of research and development personnel to total employees is higher in our case than among other contractors	
	ERB3: The focus of research and development personnel is shifting towards the development of green construction technology	
	ERB4: Collaborative projects with universities or research institutes with the goal of developing green construction technologies are pursued	
	ERB5: Advanced green construction equipment is used during the construction process	
	ERB6: Advanced green construction techniques are adopted during the construction process	
	ERB7: Clean energy is utilized during the construction process	
	ERB8: Environmentally friendly raw materials are used during the construction process	
	ERB9: Construction waste is recycled on-site	
	ERB10: Wastewater treatment facilities are introduced on-site	
	ERB11: Atmospheric pollution control facilities are introduced on-site	
	ERB12: Environmental monitoring facilities are introduced on-site, and environmental monitoring is conducted	

Table 1. Measurement of the latent variables.

This study employed a snowball sampling method and online surveys to collect questionnaire data. First, the study created an online survey on the Chinese platform "Questionnaire Star" and generated a link to the survey. The link was then distributed to initial respondents (megaproject contractors closely associated with the research team) via Chinese instant messaging platforms (WeChat and QQ). These respondents were asked to complete the survey and subsequently forward the link to other potential participants who met the criteria for this research. The choice to use a snowball sampling approach and online surveys was driven by two main considerations. First, the target population's professional nature, issues pertaining to geographical dispersion, and the closed nature of relevant projects made it difficult for the research team to obtain extensive access to such groups. Second, this method can increase the response rate, expand the coverage of the sample, and improve the representativeness and quality of the responses. In light of the potential biases inherently associated with a snowball sampling approach, the study implemented several measures to ensure sample diversity and limit bias. First, initial respondents were chosen carefully to cover diverse project types, project locations, job positions,

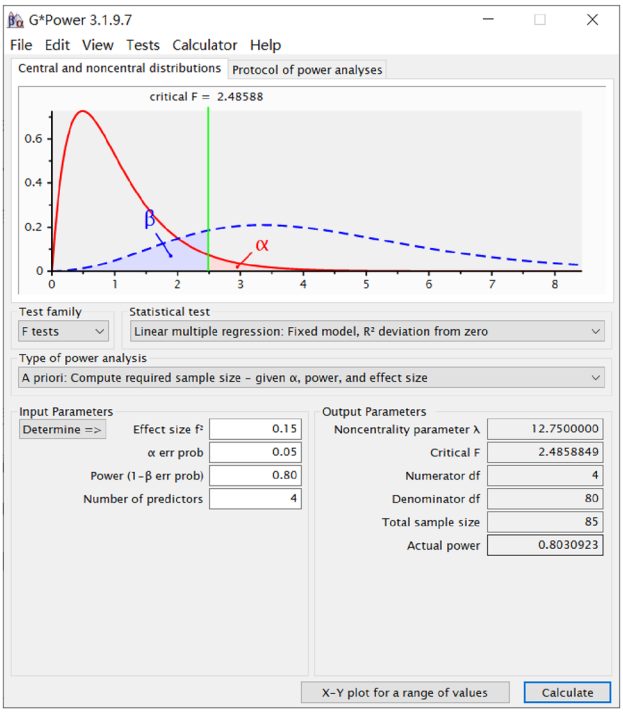

Fig. 2. G*power test performed to determine the minimum required sample size.

genders, and educational backgrounds. Second, each initial respondent was allowed to recommend a maximum of three people.

To enhance the response rate and the quality of the responses, this study implemented additional measures. The study introduced a system of small rewards to encourage participation. Furthermore, the research team maintained regular communication with initial respondents with the goals of establishing relationships with them and encouraging them to share the survey link with additional suitable participants. From December 2023 to April 2024, a total of 232 questionnaires were completed. The data were rigorously screened and 51 questionnaires (21.98%) were excluded for several reasons: (1) the respondents provided contradictory responses; (2) the responses did not meet the study requirements; and (3) the answers were overly uniform. Ultimately, 181 valid questionnaires were retained, yielding a 78.02% effective response rate. As the number of valid questionnaires exceeded the minimum sample size requirements (i.e., either 85 or 160), these 181 questionnaires were sufficient to support further data analysis. Table 2 provides demographic details of the respondents. These respondents are distributed across various project types, locations, job positions, genders, and educational backgrounds. Therefore, the sample is representative and suitable for further analysis.

In this study, since all latent variables were measured using the same questionnaire, it was necessary to consider the possibility of common method bias (CMB). Following the recommendations of Kock et al. (2021), procedural and statistical controls were used to reduce CMB[65]. In terms of procedural controls, the study implemented various measures. First, the research team assured respondents that the survey was confidential and anonymous, and emphasized the fact that there were no right or wrong answers to the questions. Second, the questionnaire did not mention the specific names of the latent variables to prevent respondents from inferring causal relationships and thus concealing their true thoughts. Third, the research team and experts rigorously reviewed and revised the questionnaire multiple times. This approach ensured the clarity and specificity of the wording of the questions, thereby avoiding the use of ambiguous or leading language. In terms of statistical controls, following the suggestions of Kock[66], the research team verified the variance inflation factor (VIF) of the inner model. The results indicate that all the VIF values associated with the inner model were below the threshold of 3.3, thus indicating that the research model seems to be unaffected by CMB.

Statistical analysis

Structural equation modeling (SEM) is a statistical analysis method used to analyze and estimate complex relationships among multiple exogenous and endogenous latent variables[13]. At present, SEM can be divided into two types: covariance-based SEM (CB-SEM) and partial least squares SEM (PLS-SEM)[13]. Based on a comparison of the applicability of these two methods, PLS-SEM appeared to be more suitable for this study. The main reason for this choice is that PLS-SEM is better suited to exploratory research aimed at theory development and studies featuring small sample sizes (less than 200)[67], which aligns closely with the nature of this study. This research employs the ETPB for theoretical development and exploratory research. Furthermore, since the study's subjects are contractors working in megaprojects, a group that is relatively small and highly specialized, the task of obtaining sample data was extremely challenging. This study ultimately collected 181 valid samples,

Characteristics of Sample	Category	Number	Percentage/%
Project type	Transportation engineering	78	43.09
	Construction engineering	64	35.36
	Water conservancy engineering	32	17.68
	Others	7	3.87
Project location	Eastern China	49	27.07
	Southern China	49	27.07
	Central China	31	17.13
	Western China	29	16.02
	Northern China	23	12.71
Position	Grassroots managers	82	45.30
	Middle managers	59	32.60
	Senior managers	40	22.10
Gender	Male	128	70.72
	Female	53	29.28
Highest level of education	Junior college or below	32	17.68
	Bachelor's degree	104	57.46
	Master's degree	32	17.68
	PhD	13	7.18

Table 2. Respondents' demographic characteristics (N = 181).

thus identifying this research as a small-sample study. Therefore, this study utilizes PLS-SEM and employs the comprehensive and advanced software known as SmartPLS 4 for data analysis[68].

Results

Assessment of the reflective measurement model

This study follows the guidelines suggested by Hair et al. (2022), which involve sequentially assessing the reflective measurement model in terms of internal consistency (reliability), convergent validity, and discriminant validity[67].

Assessment of internal consistency (reliability)

This study uses Cronbach's alpha (α) and composite reliability (CR) to assess reliability[69]. According to the results listed in Table 3, the α coefficients (ranging from 0.839 to 0.946) and CR values (ranging from 0.903 to 0.953) for all latent variables are above the recommended threshold of 0.7. Therefore, the measurement model exhibits an acceptable level of reliability.

Assessment of convergent validity

According to Hair et al. (2022), two main criteria can be used to assess convergent validity[67]. The outer loadings of the measurement indicators and their significance at the 0.05 level, as well as the average variance extracted (AVE) value. As shown in Table 3, the outer loading values of all indicators (ranging from 0.737 to 0.883) exceed the recommended threshold of 0.708 and are significant (p-value < 0.05). The AVE values (ranging from 0.629 to 0.756) also exceed the recommended threshold of 0.5. Therefore, the measurement model exhibits satisfactory convergent validity.

Assessment of discriminant validity

Hair et al. (2022) suggested that discriminant validity should be assessed through a process involving two steps[67]. First, the heterotrait-monotrait ratio (HTMT) is evaluated. Then, the HTMT value's 95% percentile bootstrap confidence interval is further assessed (using a complete bootstrapping procedure based on 10,000 subsamples, a one-tailed test, and a 0.05 significance level). As shown in Table 4, the HTMT values for all combinations of latent variables (ranging from 0.072 to 0.766) are below the more stringent threshold of 0.85. Additionally, the upper bounds of all confidence intervals are also below this threshold of 0.85. These results indicate that the measurement model exhibits good discriminant validity.

Assessment of the structural model

To evaluate the structural model, this study strictly follows the procedure outlined by Hair et al. (2022)[67]. First, it examines the multicollinearity issue within the structural model. Second, it evaluates the size and significance of the path coefficients with the goal of either rejecting or accepting the hypotheses. Third, the in-sample explanatory power of the model is assessed. The size of the effect size (f^2) is evaluated subsequently. Finally, the out-of-sample predictive power of the model is assessed.

Latent variable	Indicators	Outer loadings (> 0.708)	*p*-value (< 0.05)	AVE (> 0.5)	α (> 0.7)	CR (> 0.7)
Attitudes (ATT)	ATT1	0.804	0.000	0.708	0.897	0.924
	ATT2	0.861	0.000			
	ATT3	0.844	0.000			
	ATT4	0.879	0.000			
	ATT5	0.817	0.000			
Subjective norms (SN)	SN1	0.799	0.000	0.669	0.876	0.910
	SN2	0.786	0.000			
	SN3	0.841	0.000			
	SN4	0.836	0.000			
	SN5	0.828	0.000			
Perceived behavioral control (PBC)	PBC1	0.823	0.000	0.666	0.874	0.909
	PBC2	0.836	0.000			
	PBC3	0.737	0.000			
	PBC4	0.855	0.000			
	PBC5	0.824	0.000			
Intentions (INT)	INT1	0.869	0.000	0.756	0.839	0.903
	INT2	0.883	0.000			
	INT3	0.857	0.000			
Moral identity (MI)	MI1	0.863	0.000	0.683	0.885	0.915
	MI2	0.763	0.000			
	MI3	0.857	0.000			
	MI4	0.842	0.000			
	MI5	0.803	0.000			
Corporate green culture (CGC)	CGC1	0.816	0.000	0.654	0.897	0.919
	CGC2	0.813	0.000			
	CGC3	0.756	0.000			
	CGC4	0.777	0.000			
	CGC5	0.805	0.000			
	CGC6	0.878	0.000			
Environmentally responsible behavior (ERB)	ERB1	0.772	0.000	0.629	0.946	0.953
	ERB2	0.785	0.000			
	ERB3	0.777	0.000			
	ERB4	0.790	0.000			
	ERB5	0.785	0.000			
	ERB6	0.765	0.000			
	ERB7	0.824	0.000			
	ERB8	0.802	0.000			
	ERB9	0.811	0.000			
	ERB10	0.795	0.000			
	ERB11	0.821	0.000			
	ERB12	0.785	0.000			

Table 3. Convergent validity and reliability assessment. AVE: Average variance extracted. α: Cronbach's alpha. CR: Composite reliability, which is also referred to as rho_c.

Assessment of multicollinearity

Multicollinearity within the structural model is assessed by examining the variance inflation factor (VIF) values between all exogenous and endogenous latent variables. As shown in Table 5, all inner VIF values (ranging from 1.063 to 1.650) are below the stricter threshold of 3[70], indicating that multicollinearity is not a critical issue in the structural model.

Assessment of the size and significance of path coefficients (β)

This study evaluated the size and significance of path coefficients by performing a complete bootstrapping procedure using a percentile bootstrap method with 10,000 subsamples, a two-tailed test, and a significance level of 0.05[67]. As shown in Table 5, attitudes (H1(+): $\beta = 0.217$, t-value = 3.829, p-value < 0.001), subjective norms (H2(+): $\beta = 0.297$, t-value = 4.853, p-value < 0.001), and perceived behavioral control (H3(+): $\beta = 0.394$, t-value = 6.724, p-value < 0.001) have a positive impact on intentions. To further confirm these relationships, the

Latent variable	1	2	3	4	5	6	7
1. Attitudes							
2. Subjective norms	0.369 [0.250, 0.482]						
3. Perceived behavioral control	0.446 [0.347, 0.543]	0.556 [0.447, 0.656]					
4. Intentions	0.535 [0.432, 0.630]	0.654 [0.555, 0.743]	0.724 [0.647, 0.793]				
5. Moral identity	0.089 [0.078, 0.216]	0.147 [0.092, 0.275]	0.102 [0.088, 0.229]	0.107 [0.080, 0.236]			
6. Corporate green culture	0.098 [0.081, 0.224]	0.110 [0.088, 0.240]	0.072 [0.083, 0.186]	0.073 [0.073, 0.191]	0.257 [0.140, 0.393]		
7. Environmentally responsible behavior	0.633 [0.559, 0.702]	0.683 [0.596, 0.758]	0.754 [0.691, 0.812]	0.766 [0.689, 0.836]	0.292 [0.190, 0.411]	0.188 [0.116, 0.316]	

Table 4. Discriminant validity assessment (HTMT criterion). The brackets represent the range between the lower and upper bounds of the 95% confidence intervals (CI). HTMT value and the upper bound of its 95% CI are less than 0.85.

Model	Relationship	Inner VIF (< 3)	β	t-value (> 1.96)	p-value (< 0.05)	95% Confidence interval (excluding 0)		Conclusion	R^2 (> 0.25, 0.5, 0.75: weak, moderate, strong)	f^2 (> 0.02)	SRMR (< 0.08)
						2.5%	97.5%				
ETPB model	ATT → INT	1.221	0.217***	3.829	0.000	0.10700	0.329	H1(+) supported	0.516	0.080	0.071
	SN → INT	1.352	0.297***	4.853	0.000	0.177	0.419	H2(+) supported		0.135	
	PBC → INT	1.437	0.394***	6.724	0.000	0.276	0.504	H3(+) supported		0.223	
	PBC → ERB	1.650	0.422***	7.472	0.000	0.311	0.532	H4(+) supported	0.639	0.300	
	INT → ERB	1.650	0.402***	6.364	0.000	0.276	0.521	H5(+) supported		0.271	
	MI → ERB	1.072	0.170***	3.828	0.000	0.085	0.259	H6(+) supported		0.075	
	CGC → ERB	1.063	0.136**	2.659	0.008	0.042	0.238	H7(+) supported		0.049	
TPB model	ATT → INT	1.221	0.217***	3.829	0.000	0.107	0.329	Supported	0.516	0.080	**0.082**
	SN → INT	1.352	0.297***	4.853	0.000	0.177	0.419	Supported		0.135	
	PBC → INT	1.437	0.394***	6.724	0.000	0.276	0.504	Supported		0.223	
	PBC → ERB	1.645	0.426***	7.028	0.000	0.307	0.546	Supported	0.581	0.264	
	INT → ERB	1.645	0.419***	6.185	0.000	0.285	0.551	Supported		0.255	

Table 5. Structural model results (VIF, hypotheses testing, R^2, f^2, and SRMR). ETPB: Extended theory of planned behavior, referenced as the research model in this study. TPB: Theory of planned behavior. ATT: Attitudes. SN: Subjective norms. PBC: Perceived behavioral control. INT: Intentions. MI: Moral identity. CGC: Corporate green culture. ERB: Environmentally responsible behavior. VIF: Variance inflation factor. β: Standardized path coefficient. *: p-value < 0.05; **: p-value < 0.01; ***: p-value < 0.001. R^2: Coefficient of determination. f^2: Effect size. SRMR: Standardized root mean square residual of the estimated model. The numbers shown in bold indicate results that are considered to be unsatisfactory.

study also verified the 95% confidence intervals for H1(+), H2(+), and H3(+). The results in Table 5 show that the 95% confidence intervals for H1(+), H2(+), and H3(+) do not include zero, thus confirming H1(+), H2(+), and H3(+). Perceived behavioral control (H4(+): $\beta = 0.422$, t-value = 7.472, p-value < 0.001), intentions (H5(+): $\beta = 0.402$, t-value = 6.364, p-value < 0.001), moral identity (H6(+): $\beta = 0.170$, t-value = 3.828, p-value < 0.001), and corporate green culture (H7(+): $\beta = 0.136$, t-value = 2.659, p-value < 0.01) significantly influence ERB. The 95% confidence intervals for H4(+), H5(+), H6(+), and H7(+) also do not contain zero, further confirming their significance. Therefore, H4(+), H5(+), H6(+), and H7(+) are validated.

Assessment of in-sample explanatory power

The coefficient of determination (R^2) for endogenous latent variables is commonly used to assess the model's in-sample explanatory power[71]. R^2 reflects the extent to which the variance of an endogenous latent variable can be jointly explained by all its preceding exogenous latent variables[67]. According to Legate et al. (2023), R^2 values greater than 0.25, 0.50, and 0.75 represent weak, moderate, and strong explanatory power, respectively[72]. As shown in Table 5, the R^2 value for the endogenous latent variable intention is 0.516 (> 0.50), indicating that attitudes, subjective norms, and perceived behavioral control jointly explain 51.60% of the variance in intentions. Similarly, perceived behavioral control, intentions, moral identity, and corporate green culture jointly explain

63.90% of the variance in ERB ($R^2 = 0.639 > 0.50$). Therefore, the model demonstrates moderate in-sample predictive power in this study.

Assessment of effect size f^2

The effect size f^2 primarily reflects the change that occurs in the R^2 of an endogenous latent variable when a specific exogenous latent variable that precedes the former variable is removed[73]. The effect size f^2 quantifies the relative contribution of a specific exogenous latent variable in explaining an endogenous latent variable. As shown in Table 5, all f^2 values (ranging from 0.049 to 0.300) exceed the recommended threshold of 0.02[72]. Therefore, each exogenous latent variable makes a meaningful contribution to the explanation of the corresponding endogenous latent variables.

Assessment of out-of-sample predictive power

This study evaluated the out-of-sample predictive power of the model via two methods: (1) the $PLS_{predict}$ method[74] and (2) the cross-validated predictive ability test (CVPAT) method[75]. The study employs the $PLS_{predict}$/CVPAT procedure with 10 folds and 10 repetitions[67]. Following the recommendations of Hair et al. (2021)[71], this study focuses on analyzing the key target endogenous latent variable in the theoretical model, i.e., ERB. As shown in Table 7, the *Q*2 predict values for all measurement indicators of ERB (ranging from 0.333 to 0.439) are significantly greater than zero, thus indicating that the model exhibits predictive relevance. Additionally, the PLS-SEM analysis indicated lower root mean square error (RMSE) values than naïve linear model (LM) benchmark model with regard to ten of the twelve measurement indicators of ERB. Therefore, the model exhibits a moderate level of out-of-sample predictive power.

To further validate the out-of-sample predictive power of the model, this study also employed the more rigorous and comprehensive CVPAT method. According to Table 6, for the key target endogenous latent variable ERB, the PLS-SEM predictions show that its average loss is significantly lower than the naïve indicator-average (IA) prediction benchmark (*CVPATbenchmark_IA construct*: difference of average loss = −0.216 < 0, *p*-value < 0.001). This result indicates that the model possesses out-of-sample predictive efficacy. For the more conservative linear model (LM) prediction benchmark, the average loss shown by the PLS-SEM prediction is lower (*CVPATbenchmark_LM construct*: difference of average loss = −0.019 < 0), but this difference is not statistically significant (*p*-value = 0.102 > 0.05), suggesting that the model's out-of-sample predictive power is not exceptionally strong. For the overall model, Table 6 indicates that the average loss of the overall model is significantly lower than that of the IA benchmark (*CVPATbenchmark_IA overall*: difference of average loss = −0.229 < 0, *p*-value < 0.001) and the LM benchmark (*CVPATbenchmark_LM overall*: difference of average loss = −0.027 < 0, *p*-value < 0.05), demonstrating that the overall model possesses strong out-of-sample predictive power. In summary, both the $PLS_{predict}$ and CVPAT methods confirm that the model has adequate out-of-sample predictive power.

Comparison of the TPB and ETPB models

This study relied on the research conducted by Wong et al. (2024)[76] and Karoui et al. (2024)[73] when determining whether the ETPB model proposed in this study is superior to the TPB model. Before making the formal comparison, this study assessed the measurement model and VIF value of the TPB model, and the results indicated that both met the required standards. Following this, the study compared the model fit, path significance, in-sample explanatory power, and out-of-sample predictive power of the two models. Model fit was primarily assessed in terms of the standardized root mean square residual (SRMR)[77]. As shown in Table 5, the SRMR value of the ETPB model (0.071) is below 0.08, whereas the SRMR value of the TPB model (0.082) exceeds 0.08. These results suggest that the ETPB model has a slightly better fit[78]. However, Hair et al. (2022) cautioned that model fit indices in PLS-SEM remain under development[67]. Therefore, we also compared the path significance, in-sample explanatory power, and out-of-sample predictive power of the two models.

As shown in Table 5, the ETPB model is associated with more significant paths compared to the TPB model. Additionally, the R^2 value for ERB in the ETPB model (0.639) is higher than the corresponding value in the TPB model (0.581). These results indicate that the ETPB model is more comprehensive and has stronger in-sample explanatory power than the TPB model. Table 7 indicates that in the TPB model's $PLS_{predict}$ results, the *Q*2 predict values for all measurement indicators are significantly greater than zero, thus indicating predictive relevance. However, the PLS-SEM analysis revealed a higher level of prediction errors than did the LM benchmark for more than half of the indicators of key target endogenous latent variable, i.e., ERB, thus indicating weak out-of-

Focus on ERB and overall model		ETPB model		TPB model	
		Average loss difference (< 0)	*p*-value (< 0.05)	Average loss difference (< 0)	*p*-value (< 0.05)
ERB	*CVPATbenchmark_IA construct*	−0.216	0.000	−0.198	0.000
	CVPATbenchmark_LM construct	−0.019	**0.102**	**0.002**	**0.880**
Overall model	*CVPATbenchmark_IA overall*	−0.229	0.000	−0.214	0.000
	CVPATbenchmark_LM overall	−0.027	0.010	−0.003	**0.733**

Table 6. CVPAT results for out-of-sample prediction power. ERB: Environmentally responsible behavior. ETPB: Extended theory of planned behavior, referenced as the research model in this study. TPB: Theory of planned behavior. CVPAT: Cross-validated predictive ability test. IA: Indicator-average. LM: Linear model. Numbers in bold indicate results that are considered to be unsatisfactory.

ETPB model						TPB model				
Indicators	Q2 predict (> 0)	$RMSE_{PLS\text{-}SEM}$	$RMSE_{LM}$	$RMSE_{PLS\text{-}SEM} - RMSE_{LM}$ (< 0)	Predictive relevance	Q2 predict (> 0)	$RMSE_{PLS\text{-}SEM}$	$RMSE_{LM}$	$RMSE_{PLS\text{-}SEM} - RMSE_{LM}$ (< 0)	Predictive relevance
INT1	0.417	0.684	0.728	− 0.044	Strong	0.417	0.684	0.703	− 0.019	Strong
INT2	0.375	0.679	0.716	− 0.037		0.375	0.679	0.687	− 0.008	
INT3	0.322	0.690	0.731	− 0.041		0.322	0.690	0.711	− 0.021	
ERB1	0.369	0.587	0.604	− 0.017	Moderate	0.346	0.597	0.590	**0.007**	Weak
ERB2	0.395	0.573	0.577	− 0.004		0.317	0.609	0.606	**0.003**	
ERB3	0.439	0.564	0.605	− 0.041		0.388	0.590	0.608	− 0.018	
ERB4	0.333	0.590	0.604	− 0.014		0.317	0.597	0.589	**0.008**	
ERB5	0.384	0.582	0.599	− 0.017		0.363	0.592	0.587	**0.005**	
ERB6	0.432	0.579	0.600	− 0.021		0.383	0.604	0.605	− 0.001	
ERB7	0.431	0.558	0.571	− 0.013		0.410	0.568	0.564	**0.004**	
ERB8	0.353	0.611	0.651	− 0.040		0.330	0.622	0.628	− 0.006	
ERB9	0.387	0.562	0.562	**0.000**		0.370	0.570	0.556	**0.014**	
ERB10	0.369	0.597	0.630	− 0.033		0.346	0.608	0.618	− 0.010	
ERB11	0.400	0.594	0.607	− 0.013		0.354	0.616	0.618	− 0.002	
ERB12	0.360	0.599	0.581	**0.018**		0.349	0.604	0.589	**0.015**	

Table 7. $PLS_{predict}$ results for out-of-sample prediction power. ETPB: Extended theory of planned behavior, referenced as the research model in this study. TPB: Theory of planned behavior. INT1 to INT3 represent the three measurement indicators of intentions (INT). ERB1 to ERB12 represent the twelve measurement indicators of environmentally responsible behavior (ERB). RMSE: Root mean squared error. PLS-SEM: Partial least squares structural equation modeling. LM: Linear model. The numbers shown in bold represents the measurement indicators of the key target endogenous latent variable and their final results.

sample predictive power. Table 6 indicates that the CVPAT results of the TPB model reveal that the average loss associated with the latent variable ERB is greater than that associated with the LM benchmark. Furthermore, although the average loss of the overall model in the TPB model is lower than the corresponding value in the LM benchmark, this difference is not statistically significant. Therefore, the ETPB model demonstrates stronger out-of-sample predictive power compared to the TPB model. In light of the preceding analysis, this study has ample reason to conclude that the ETPB model is superior to the TPB model.

Robustness checks

Robustness checks are crucial for ensuring the stability and validity of research results and conclusions[79]. Vaithilingam et al. (2024) emphasized the fact that robustness checking is an indispensable component of research when applying PLS-SEM[80]. Following the suggestions of Sarstedt et al. (2020), the robustness checks for the model employed in this study primarily concern the following three aspects: (1) nonlinear effects; (2) endogeneity; and (3) unobserved heterogeneity[81].

Assessment of nonlinear effects

To ensure linearity between the exogenous and endogenous latent variables in the structural model, this study conducted two tests, following the suggestions of Sarstedt et al.[81]. First, interaction terms were added to the original model to represent quadratic effects among (1) attitudes, subjective norms, and perceived behavioral control on intentions, and (2) perceived behavioral control, intentions, moral identity, and corporate green culture on ERB[81]. The bootstrapping procedure (with parameter settings consistent with those discussed in "Assessment of the structural model") and the PLS-SEM algorithm offered by SmartPLS 4 were used to obtain the corresponding test results[82]. The results indicate that all p-values are > 0.05, and all f^2 values are below the minimum threshold of 0.02 (Supplementary Table S1), thus suggesting that the quadratic effects in all relationships are not significant. Next, to test for nonlinear effects in further detail, the study used the latent variable scores from the original model obtained via the PLS-SEM algorithm to conduct a Ramsey's regression specification error test (RESET)[83]. Under the guidance of Marko and Erik (2019)[84], this study conducted the Ramsey's RESET in SPSS 27. The results reveal that neither the partial regression of intentions on attitudes, subjective norms, and perceived behavioral control (F (2, 175) = 0.090, p-value = 0.914 > 0.05) nor the partial regression of ERB on perceived behavioral control, intentions, moral identity, and corporate green culture (F (2, 174) = 0.954, p-value = 0.387 > 0.05) are not influenced by nonlinear effects (Supplementary Table S1). Therefore, the linearity of the relationships in the study model is sufficiently confirmed[79,81].

Assessment of endogeneity

Simultaneous or reverse causality, as well as omitted variables, can often lead to potential endogeneity issues in models[80,81], which might lead researchers to draw misleading conclusions. Endogeneity is a critical issue in PLS-SEM studies, as such studies involve a causal predictive approach[71]. This study employs the Gaussian copula method to examine endogeneity issues within the model, as this method is more precise[85] and has been

highly recommended for PLS-SEM research[80]. This study follows the guidance of Hult et al. (2018)[86], Lim et al. (2024)[87], and Riggs et al. (2024)[82], by implementing the Gaussian copula method with the assistance of SmartPLS 4 to test for potential endogeneity issues in the model. Initially, the Kolmogorov–Smirnov test with Lilliefors correction (completed in SPSS 27) was performed on all antecedent latent variable scores. The results indicate that all latent variables in the study are non-normally distributed (p-value < 0.05), thus satisfying the prerequisite for using the Gaussian copula method. Subsequently, this study conducted Gaussian copula analysis via the bootstrapping procedure with the assistance of SmartPLS 4 (with parameter settings consistent with those described in Assessment of the structural model). The findings indicate that all the results of the Gaussian copula test are not significant (p-value > 0.05) (Supplementary Table S2), thus suggesting that endogeneity is not a major issue in this study.

Assessment of unobserved heterogeneity

PLS-SEM typically assumes that data are collected from homogeneous populations[76]. However, this assumption overlooks the fact that unobservable characteristics may cause latent heterogeneity within the dataset, thus leading to the segmentation of the dataset into different groups[88]. Such unobserved heterogeneity poses a threat to the validity of the results of such research[81]. To check for unobserved heterogeneity, this study used the most advanced finite mixture partial least squares (FIMIX-PLS) method currently available[88]. First, this study determined the maximum number of segments to extract. As discussed in "Participants and procedure", the minimum sample size requirement for this study is 85. Given the actual effective sample size of 181 in this study, the maximum number of segments is calculated as: 181/85 = 2 (rounded down). Subsequent, the study utilized the default parameter settings in SmartPLS 4 (a stop criterion of 10^{-7}, a maximum number of iterations of 5000, and the number of repetitions of 10) and sequentially ran FIMIX-PLS from 1 to 2 segments. Finally, in line with the recommendations of Sarstedt et al. (2022)[88], this study compared the values generated by the following criteria: (1) modified Akaike's information criterion with factor 3 (AIC_3) and consistent Akaike's information criterion (CAIC); (2) Akaike's information criterion (AIC) and minimum description length with factor 5 (MDL_5); and (3) normed entropy statistic (EN). If the results of (1), (2), and (3) all indicate a one-segment solution or reveal varied preferences for different segmentation solutions, the findings indicate the absence of unobserved heterogeneity [81]. The results show that AIC_3 and CAIC indicate a one-segment solution and a two-segment solution, respectively, and the same applies for AIC and MDL_5 (Supplementary Table S3). Since these criteria do not uniformly point to the same segmentation solution, the data in this study appear to lack unobserved heterogeneity. Furthermore, this study compared the EN values. Since the EN value for the two-segment solution is less than 0.5, the two-segment solution is deemed unsuitable. Therefore, unobserved heterogeneity is indeed not an issue in this study.

Discussion

Discussion of findings

Although scholars have used the TPB or its extended versions to explain and predict contractors' ERB, this study introduces a novel ETPB model. This model incorporates the variables of moral identity and corporate green culture and their impacts on ERB. Additionally, this study was conducted in the context of megaprojects, thus distinguishing it from most previous studies in the field, which have focused primarily on the ERB of contractors in general projects. This study revealed that the ETPB model outperforms the TPB model in terms of model fit, explanatory power, and predictive power.

This study proposed seven hypotheses, all of which were confirmed. First, this research highlighted the importance of a correct attitude with regard to foster contractors' intentions to engage in ERB. The results revealed a significant positive correlation between contractors' attitudes and their intentions for ERB. This conclusion is perfectly in line with the findings reported by Xie et al. (2022)[14]. Those researchers also successfully demonstrated that attitudes are a critical predictive variable for intentions in their study on megaproject ERB. Additionally, the conclusions of this study completely matched those of research conducted in the field of general projects. For instance, Li et al. (2023) found that if contractors adopt positive attitudes towards green development behavior, their intentions are also activated[89]. Similar conclusions were reported by Wu et al. (2017)[24] and Gao et al. (2023)[31]. Therefore, the findings of this study revalidate the perspectives of previous scholars on this topic. More importantly, this study reveals that attitudes constitute a powerful predictor of contractors' intentions, regardless of whether the context under investigation is a megaproject or general project.

The results of this study also demonstrate that subjective norms have a positive effect on people's intentions for ERB, thus reaffirming the perspective of Xie et al. (2022)[14]. Additionally, with regard to studies conducted in the context of general projects, Wu et al. (2017) also supported the claim that subjective norms can inspire contractors to take environmentally responsible actions[24]. However, an interesting divergence can be observed with regard to another study conducted in the context of a general project. Jain et al. (2020) investigated contractors' waste recycling behavior and reported no significant positive relationship between subjective norms and intentions[34]. This study posits that differences in the sociocultural and institutional contexts of various countries are significant factors that can account for the differing conclusions of these two studies. Wu et al. (2017)[24] focused on mainland China, whereas Jain et al.[34] investigated India. The Chinese context is influenced by Confucian culture, which emphasizes social harmony and "face". Therefore, Chinese contractors may attribute greater importance to external social expectations and support than Indian contractors. The findings of this study confirm the influence of subjective norms on Chinese contractors. Additionally, this study reveals that the role of subjective norms varies across different cultural and institutional settings.

Additionally, this study found that perceived behavioral control significantly positively affects contractors' intentions and actual ERB. This conclusion diverges from studies conducted in the context of general projects. Wu et al. (2017) did not find that perceived behavioral control stimulates contractors' intentions[24]. In a study

on contractors' green development behavior, Li et al. (2023) indicated that while perceived behavioral control affects contractors' intentions, it does not directly influence their final behaviors[89]. This study suggests that the fundamental reason underlying these differences is the variation in the subjects of these surveys. Contractors in megaprojects possess stronger comprehensive capabilities and have more opportunities to access various resources and forms of support. Therefore, perceived behavioral control is more likely to result in intentions and actual behavior in megaproject contractors than in general contractors. To further validate the findings of this study, previous research focusing on megaproject contractors as the primary subjects was reviewed. Xie et al. (2022)[14] and Gao et al. (2023)[31] both produced conclusions consistent with this study. Additionally, the results of this study show that perceived behavioral control has the largest impact on both intentions ($\beta = 0.394$, $f^2 = 0.223$) and ERB ($\beta = 0.422$, $f^2 = 0.300$).

This study also confirms that intention is a critical predictor of ERB. The stronger contractors' intention is, the more likely they are to implement ERB. This conclusion holds true for both contractors working on megaprojects and general contractors. Xie et al. (2022) investigated ERB in the context of megaprojects and revealed a positive relationship between intention and behavior[14]. With regard to general contractors, Maqsoom et al. (2023) found that intentions can promote green behavior among such contractors[90]. In the study on green development behavior by Li et al. (2023), intentions have a positive impact on behavior[89]. Li et al. (2022), who explored contractors' construction waste reduction behavior, also confirmed the influence of intention on behavior[91]. Similar conclusions have been drawn by other scholars, such as Gao et al. (2023)[31] and Jain et al. (2020)[34]. Therefore, intentions represent an indispensable antecedent in efforts to encourage contractors to engage in ERB.

To enhance the explanatory and predictive power of the TPB for contractors' ERB, this study also explored moral and green cultural factors that are not included in the TPB. In previous studies on contractors' ERB, the ETPB has mostly been applied in the context of general projects[91,92] and that few studies have investigated megaprojects. Therefore, the findings of this study provide a potential avenue for applying the ETPB in the context of megaprojects.

Specifically, with regard to moral factors, this study primarily considers the variable of moral identity. The findings indicate a significant positive correlation between moral identity and contractors' ERB. Moral identity influences behavior through the internalization of ethical standards and the desire to maintain self-consistency, that is, the alignment between one's actions and moral cognition[45]. Contractors with a high level of moral identity are more likely to internalize environmental responsibility as part of their self-concept and to regard it as an intrinsic moral obligation[44]. Therefore, even in the absence of external regulation, such individuals proactively engage in ERB in order to uphold their moral self-concept. With regard to green cultural factors, this study primarily examines corporate green culture. The findings reveal that under the influence of corporate green culture, the likelihood of contractors proactively implementing ERB increases. Contractors embedded in a green culture are more inclined to integrate environmental values into their daily operations and decision-making processes[59]. For example, they may formulate environmental policies, conduct green training programs, and implement green performance evaluations. Such cultural norms foster a supportive organizational climate[50]. Within this context, green principles become a shared code of conduct, whereby ERB is both expected and encouraged, ultimately becoming routine practice rather than an optional initiative. Additionally, this study examined the path coefficients and f^2 and revealed that the direct impacts of moral identity ($\beta = 0.170$, $f^2 = 0.075$) and corporate green culture ($\beta = 0.136$, $f^2 = 0.049$) on ERB are not as strong as those of other latent variables. The study posits that this difference is primarily due to the fact that the effects of moral identity and corporate green culture are subtle and require prolonged effort to yield significant results. Nevertheless, these findings clearly demonstrate that the significant influence of moral identity and corporate green culture on ERB is objectively present.

It is important to note that this study validates the ETPB model within the context of Chinese culture. Therefore, the relationships and conclusions identified in this study may be influenced by specific cultural attributes. For instance, Chinese culture, deeply rooted in Confucianism, emphasizes collectivism, moral ethics, social responsibility, and the concept of "face." Within such a cultural environment, Chinese contractors tend to place greater value on social expectations, collective interests, and organizational norms. This cultural orientation may amplify the influence of subjective norms, moral identity, and corporate green culture on behavioral intention and ERB. In contrast, in cultures dominated by individualism, contractors may place more emphasis on whether ERB yields economic benefits when deciding whether to engage in such actions. Therefore, the connections between non-economic factors and ERB may be relatively weaker. The direct influence of moral identity and corporate green culture on contractors' ERB may also be less pronounced in individualistic cultures compared to collectivist ones. Accordingly, different cultural dimensions can affect the interpretation and practical application of the ETPB model proposed in this study. To ensure the model's validity and applicability, cultural differences must be taken into account when applying and interpreting the ETPB model across diverse cultural settings.

Theoretical implications

In previous research, the TPB has been applied in studies of both individual and organizational ERB, although it has been used most commonly at the individual level. The support for hypotheses H1(+), H2(+), H3(+), H4(+), and H5(+) in this study indicates that the TPB can explain and predict complex organizational ERB. Therefore, this study reaffirms the effectiveness and reliability of the TPB in the context of organizational ERB. Additionally, previous organizational-level research has rarely focused on contractors within the context of megaprojects. This study extends the scope of application of the TPB to encompass the temporary organizations involved in megaprojects, thereby enriching the literature on organizational ERB and facilitating the application of the TPB in other organizational contexts.

Additionally, this study successfully confirmed the significant roles of moral factors (moral identity) and green cultural factors (corporate green culture) in explaining and predicting the ERB of megaproject contractors. The findings concerning H6(+) and H7(+) reveal that both moral identity and corporate green culture have significant positive impacts on the ERB of megaproject contractors. Furthermore, since the TPB fails to take many factors into consideration, most scholars have attempted to compensate for this limitation by integrating additional variables into the TPB to enhance its explanatory and predictive power. However, the ETPB has rarely been applied to research on ERB among megaproject contractors. This research introduced moral identity and corporate green culture into the TPB and successfully validated the feasibility and effectiveness of the ETPB. Therefore, this study addresses relevant gaps in the TPB, thereby providing new pathways and perspectives for the extension of this theory. Furthermore, this research fills a gap in the study of ERB among megaproject contractors using the ETPB by offering a new theoretical framework and research perspective in this field.

Practical implications

Based on the results of this empirical research and discussion, this study proposes the following recommendations to encourage contractors to actively implement ERB during the process of megaproject construction:

From the perspective of the government, it is essential to strengthen the promotion of ERB. The content of such promotional efforts should not only emphasize the positive social impacts of ERB but also highlight the commercial benefits it offers to contractors. Furthermore, the government should adhere to a balanced approach that integrates both incentives and penalties. On the one hand, it is necessary to formulate and strictly enforce laws and regulations related to environmental protection in megaprojects. On the other hand, a diversified incentive mechanism should be established, including financial subsidies, green credit support, awards for green construction practices, and evaluations of moral and green culture development. Furthermore, the government should endeavor to establish a robust system of social oversight. This may include conducting regular surveys to assess the satisfaction of residents living near construction sites, as well as setting up dedicated hotlines for reporting pollution-related incidents. Such measures aim to enhance public participation in environmental governance. Simultaneously, the government should encourage media outlets to establish dedicated columns focused on green construction in megaprojects. These platforms should provide continuous coverage throughout the entire construction process, criticize contractors' polluting behaviors, and promote environmentally friendly actions.

From the perspective of project owners, selecting an appropriate contractor to undertake megaprojects is of critical importance. The findings of this study indicate that perceived behavioral control, moral identity, and corporate green culture positively influence the implementation of ERB by contractors. Therefore, during the contractor prequalification process, project owners should assess both the contractor's capacity to implement ERB (such as the availability of environmental protection funds, qualified personnel, green construction technologies, and relevant practical experience) and the level of development in their moral and green cultural development. Furthermore, project owners should emphasize the concept of green and environmentally sustainable development in megaprojects. Project owners should explicitly state specific environmental protection requirements and standards in tender documents. During the contract signing process, project owners should make the results of green environmental assessments a requirement for the successful acceptance of the project. Furthermore, project owners should establish a performance-based reward and penalty mechanism related to contractors' ERB. Contractors who meet the required environmental performance standards may be rewarded through financial incentives or offered future collaboration opportunities. Conversely, contractors who fail to meet these standards should be subject to corresponding financial penalties.

From the perspective of the contractor firm, collaboration with universities or relevant research institutions is essential. Such partnerships can help introduce specialized talent and jointly develop advanced green construction technologies and management methods. Furthermore, contractors should pay careful attention to and analyze the environmental protection policies of local and central governments. Contractors should strictly avoid crossing legal boundaries while actively seeking policy support to access more resources. These measures are conducive to enhancing contractors' perceived behavioral control over the implementation of ERB. This study confirms the significant roles of moral identity and corporate green culture in the process of promoting contractors' ERB. Therefore, contractors should strengthen moral education and environmental ethics training, while establishing a moral role model mechanism to recognize and publicize exemplary environmentally ethical behavior. Simultaneously, contractors should develop clear ethical guidelines, implement comprehensive reporting mechanisms and ethics hotlines, and enforce appropriate disciplinary measures against violations of environmental ethics. Furthermore, contractors should continuously promote green values through internal communication platforms and actively organize initiatives such as green culture festivals and environmental public welfare activities. The green philosophy should also be integrated into the company's strategic planning and institutional framework. They should also improve environmental assessment mechanisms, strengthening green incentive measures, and further cultivating and reinforcing a robust corporate green culture.

From the perspective of site managers, cultivating a correct and comprehensive understanding of ERB is of critical importance. Site managers must strictly adhere to and implement all environmental protection standards and requirements mandated by relevant stakeholders. They should also integrate these standards into construction organization designs and detailed site management procedures. Furthermore, site managers should establish open communication mechanisms for project-related information. This mechanism may include organizing regular community site visits, setting up feedback channels for residents, and actively responding to environmental supervision feedback from media and governmental authorities. Site managers should also participate regularly in training programs related to green construction and actively engage in industry exchange conferences. Through these activities, site managers can acquire advanced green construction technologies and management practices, thereby improving their overall managerial competencies. Furthermore, site managers

should lead by example, actively embodying and promoting ethical standards and green cultural values. This approach can be achieved by displaying environmental protection slogans and moral commitment statements at construction sites to create a strong atmosphere of environmental consciousness. Such efforts help foster a collective sense of environmental responsibility within the team, thereby driving the effective implementation of ERB.

Conclusion

This study utilized an ETPB model that incorporates moral identity and corporate green culture into the TPB to explain and predict the ERB exhibited by megaproject contractors. The study employed the PLS-SEM method to perform empirical tests of 181 questionnaires collected from megaproject contractors in China. The study revealed that attitudes, subjective norms, and perceived behavioral control positively influence people's intentions to engage in ERB. Intentions, moral identity, and corporate green culture positively influence ERB. Furthermore, the results indicate that the ETPB model proposed in this study exhibits good explanatory and predictive power and can outperform the TPB model in these aspects.

As with previous empirical studies, although this research makes significant theoretical and practical implications, it cannot completely avoid certain limitations. First, this study employed a cross-sectional method and thus overlooked the dynamic changes that occur in the relationships among the variables under study. Future researchers can employ a longitudinal approach to understand the changes that occur in ERB and the corresponding influencing factors over time for megaproject contractors. Second, the use of snowball sampling, a non-probability sampling technique, may introduce selection bias and affect the representativeness and generalizability of the findings. Future research could utilize more representative sampling methods, such as stratified sampling, to enhance the breadth and robustness of the sample. Third, while this study focuses on megaproject contractors, the sample is restricted to China and involves a relatively small number of respondents. Future research could expand the sample scope and conduct cross-national and cross-cultural comparative studies to examine the applicability of the findings across different cultural and institutional contexts. In addition, future research could also explore the differences in findings between contractors involved in megaprojects and those in general projects. Fourth, this study included moral identity and corporate green culture in the TPB as antecedent influencing factors that can influence ERB. Future research could consider the indirect effects or moderating roles of moral identity and corporate green culture in this context. Furthermore, future research can incorporate other variables to improve our ability to explain and predict contractors' ERB. Fifth, this study primarily focuses on the linear mechanisms underlying ERB, with limited consideration of potential nonlinear influences. Future research could adopt mixed-method approaches such as in-depth interviews or case studies to explore the possible existence of nonlinear mechanisms driving ERB.

Ethical statement

This study was conducted using data obtained solely through a questionnaire survey carried out by the authors. And in alignment with ethical standards, we confirm the following: All methods were carried out in accordance with relevant guidelines and regulations. All experimental protocols were approved by Changsha University of Science and Technology. Informed consent was obtained from all subjects and/or their legal guardian(s).

Data availability

Data will be made available on request to the corresponding author via zhao.zhai@csust.edu.cn.

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Author contributions

ZZ conceptualized the study. SG wrote the original draft and prepared all the figures and tables. ZZ, SG and MS revised the draft and finalized it.

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Declarations

Competing interests
The authors declare no competing interests.

Additional information
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