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The Relationship between BIM Application and Project Sustainability Performance: Mediation Role of Green Innovation and Moderating Role of Institutional Pressures

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Abstract: Project sustainability has become a research hotspot in the construction industry and a crucial driving force for the successful delivery of projects. How enterprises can improve project sustainability performance and realize sustainable development by applying BIM has become an important research topic. In this study, based on the resource-based view and institutional theory, a relationship model of BIM application affecting project sustainability performance is constructed, and data from 449 questionnaires with electric power construction industry practitioners obtained by the two-stage data collection method are used to explore the relationship between BIM application and project sustainability performance, and to investigate the mediating role of green innovation and the moderating role of institutional pressures. The study found that: (1) BIM application has a significant positive impact on project sustainability performance; (2) BIM application has a significant positive predictive effect on green innovation, and green innovation plays a mediating role in the relationship between BIM application and project sustainability performance; and (3) under a high degree of institutional pressures, the positive relationship between BIM application and green innovation is strengthened, and, in this case, the mediating role of green innovation is enhanced. The study results help to expand the theoretical analysis of the relationship between BIM application and project sustainability performance and provide practical guidance for improving project sustainability. Finally, the data in this study only come from the power construction industry and do not differentiate between the types of green innovations, and further research could be conducted on these two aspects in the future.

Keywords: BIM application; project sustainability performance; green innovation; institutional pressures; resource-based view; institutional theory; power gird construction project; firm; model; environments

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1. Introduction

Digital technologies employed by the architecture, engineering, and construction industry are defined as information and communication technologies that are employed to create, store, exchange, or process information and facilitate communication between stakeholders [1]. Digital technologies promote the transformation of the construction industry by changing traditional ways of working and collaboration [2,3], enabling data-driven decision-making mechanisms [4,5], and enhancing the efficiency of construction [1]. Building information modeling (BIM) technology, a representative of digital technology in the construction industry, has shown the advantages of visual design, information transfer, and risk identification in construction projects [6]. Most of the existing literature emphasizes the improvement of project performance by BIM mainly in the aspects of cost, time, and quality [7]. However, there is still a significant gap between the current performance and potential performance of BIM applications. According to the Analysis Report of BIM Application in China's Construction Industry (2022), 25% of design companies and 33% of construction companies believe that they have only experienced a small portion of the value created by BIM [8]. As the requirements for greening the economy and society continue to increase, incorporating sustainability issues into the delivery of construction projects is becoming a common trend [9–12]. Current studies have demonstrated the positive impact of BIM on promoting project sustainability performance [13]. In order to gain insight into the relationship between BIM technology on project sustainability performance, several research gaps should be addressed.

First, the path of influence between BIM applications and project sustainability performance has not yet been recognized. Some studies focus on the direct relationship between BIM and project sustainability performance. For instance, Olawumi and Chan (2018) utilized the Delphi method to investigate the direct impact of BIM on project sustainability performance from the perspective of stakeholders, which is reflected in the improvement of project design solutions, the enhancement of construction quality and efficiency, and the improvement of the energy efficiency of buildings [13]. Omer et al. (2022) found that the personality traits of leaders influence the application of BIM technology, which, in turn, enhances the sustainability performance of the project [14]. Other studies have attempted to identify implementation paths to improve project sustainability performance [13,15]. For example, Li et al. (2022) pointed out that BIM contributes directly to project sustainability performance based on the organizational information processing theory and stakeholder theory and that stakeholder collaboration plays a mediating role [16]. Tang et al. (2019) argued that the adoption of BIM and Internet of Things (IoT) technologies has a positive effect on the co-ordination and co-operation behaviors among stakeholders, which improves off-site manufacturing performance [17]. Hadi et al. (2021) stated that organizational culture changes triggered by digital technologies contribute to sustainability performance [18]. Considering that sustainability in construction projects is mainly viewed from the triple bottom line consisting of environmental, social, and economic components [19], obviously, there is a research gap in the current academic discussion on the key mediating variables of BIM affecting the sustainability performance of projects. Asadi et al. (2020) claimed that engaging in green innovation can significantly improve the sustainability performance of the hotel industry. [20]. According to the resource-based view, enterprises can enhance their green innovation capability, obtain green competitive advantage, and realize sustainable development by deeply applying digital technology and fully integrating the knowledge, information, and technology resources related to green innovation [21]. Therefore, this study will investigate the role of green innovation in BIM application to affect project sustainability performance.

Meanwhile, according to the institutional theory, companies are deeply embedded in the institutional environment, and their innovative behaviors are jointly affected by the internal and external environment [22,23]. Therefore, the relationship between BIM application and green innovation may be affected by external institutional pressures. But fewer studies have investigated institutional pressures as a key boundary factor; prior research has examined institutional pressures on BIM identity in response to project technicians' resistance to using BIM technology and found that regulatory pressure, normative pressure, and imitative pressure are all positively associated with BIM identity [24]. To obtain the necessary support and resources for organizational production from the external institutional environment, enterprises tend to adopt the strategies and behaviors accepted and recognized by the external stakeholders in the field and gain organizational legitimacy by obeying the institutional pressures [25]. That is, external institutional pressures are an external driving factor that stimulates enterprises to further invest digital resources in green innovation practices. Therefore, it is of significant importance to investigate the moderating role of institutional pressures between BIM application and green innovation, in order to further clarify the boundary conditions to promote green innovation and the sustainable development of project-based enterprises.

Finally, BIM only reflects the information of a single construction project and, thus, cannot meet the needs of information exchange within a grid network and between different grids in power grid engineering [26]. For this reason, the State Grid Corporation of China has developed grid information modeling (GIM) based on BIM to enable the digital representation of information to meet the three-dimensional design needs of smart grid construction projects, thereby overcoming the defects of the previous BIM. In this context, this study will empirically investigate the impact of BIM technology on project sustainability performance, as well as the mediating role of green innovation and the moderating role of institutional pressures based on the resource-based view, institutional theory, and the source of experimental support data GIM technology. Problems to be solved include the following: (1) Finding the influence path of BIM application on project sustainability performance; (2) Determining the key boundary factors of the influence path; and (3) Making relevant recommendations on how construction companies can apply BIM technology to improve project sustainability performance. The rest of this paper is organized as follows: Section 2 conducts a theoretical review to present the research hypotheses; Section 3 describes the research methodology of this paper; Section 4 presents the data analysis and results; and Section 5 provides the research conclusions and insights.

2. Theoretical Analysis and Research Hypothesis

2.1. BIM Application and Project Sustainability Performance

This study believes that BIM application can improve project sustainability performance. The triple bottom line principle of sustainable development not only requires construction projects to focus on economic benefits, but also needs to take into account environmental and social benefits, so as to realize the sustainable development of the economy and the environment. Referring to the study of Martens et al. (2017), project sustainability performance in this paper covers three aspects: economic performance, environmental performance, and social responsibility performance [19].

BIM application improves the accuracy and timeliness of information acquisition throughout the project lifecycle [27,28]. First, timely and accurate information can reduce rework by reducing design errors in the development and management phases of a project, which, in turn, improves economic performance [29]. Lee et al. (2012) found that the use of BIM to reduce project rework contributes to an investment return of up to 15 times, where potential design defects with a serious impact on schedule can significantly affect the direct cost of the project, which is a large improvement over the cost of a project without exploiting the significant economic performance improvement of BIM projects [30]. Secondly, in the engineering project management phase, real-time quality control is an important method to control project schedules and cost overruns, and BIM can provide real-time on-site quality information collection and processing, which helps to identify potential construction defects and, thus, support real-time quality control [31]. Finally, BIM has great application potential in the facility management phase of construction projects, and these application areas include locating components, real-time data access, and equipment maintenance [32]. Construction management information platforms also provide key data mining and information processing services and share configurable computing resources, further contributing to the economic performance of projects [33].

This study shows that BIM application will reduce the potential uncertainties associated with environmental management and have a positive effect on environmental performance. The BIM application software in the design phase allows the simulation and analysis of the natural lighting, natural ventilation, and spatial pattern of the building, and the results are significant, i.e., reducing resource consumption by more than 23% and carbon emissions by more than 17% per year [34]. In the construction phase, BIM is utilized as a link between the assembly building and enterprise resource planning, which combines large-scale engineering production prefabrication processes with activities on the construction site, and the advantages of this link are demonstrated in construction schedule control, logistics, and transportation management [35]. By using digital technology to support sustainable design and construction, companies can accurately develop detailed production plans and control workflows to maximize resource efficiency and minimize resource waste [36]. In the facility management phase, Zoghi and Kim (2020) employed system dynamics to analyze the positive impact of BIM on building demolition waste, and it was found that BIM not only reduces construction waste but also decreases demolition costs by 57% [37]. Additionally, BIM can be developed twice to enhance its advantages. For instance, Shi and Xu (2021) established a BIM-based information system for construction waste prediction and demolition, which increases the recycling rate and reduces environmental pollution from landfills by detecting and controlling construction waste [38].

This paper further proposes that BIM application may improve social performance related to the needs of the public and the housing population [19]. Zoghi et al. (2021) found that a high level of BIM application can improve the social performance of a construction project by about 33%, which is manifested in resource savings, the promotion of preventive safety actions, and socio-environmental aspects [39]. Firstly, carbon emissions, which governments around the world are grappling with, are closely related to the construction industry, and BIM provides a new possibility for reducing carbon emissions in the context of sustainable project delivery [40]. Carbon emissions from buildings include implicit carbon from the production of building materials and operational carbon from energy consumption during daily operations [41]. Existing studies have found that BIM can reduce implied carbon by optimizing the structural design of a building and selecting appropriate building materials in the early design phase [42]. Secondly, the automatic review system for pit engineering compliance developed by combining algorithmic modeling tools with BIM enhances the safety prediction and reduces the significant risks associated with landslides and falls [43]. Finally, BIM can simulate sunlight on buildings and identify factors that cause user discomfort, thereby improving user satisfaction [44]. Biagini et al. (2016) proposed a reverse modeling methodology that combines BIM and laser scanning technology to provide a new approach for the renovation and restoration of historical architectural heritage, which can be employed to increase public satisfaction with the project and, thus, improve the social performance of the project [45]. Thus, the following hypothesis is proposed in this paper.

H1: *BIM application has a significant positive effect on project sustainability performance.*

2.2. BIM Application and Green Innovation

Green innovation refers to technological innovations related to green products or processes, and it includes hardware and software innovations related to energy conservation, alternative energy production, waste treatment, and pollution prevention [46]. Green building is a representative of green products in the construction industry, which aims to handle the global energy crisis and carbon emission problems through technological innovations or rational designs and operations [47]. According to the resource base view, technological resources are the key to enhancing innovation capability. In the era of the digital economy, digital technology is an important technological resource for enterprises as it helps to improve their green innovation ability and realize sustainable development by enhancing resource allocation efficiency [48].

This study argues that BIM related to green buildings can promote green innovation. First, from the perspective of stakeholders, building energy efficiency is the main criterion for green building evaluation, but it is accompanied by an increase in cost, so construction units do not have a high willingness to spontaneously enhance building energy efficiency. Recent studies have found that combining BIM simulation and value engineering in the design phase can identify the green design solution with the optimal project cost-effectiveness and find a balance point between green building evaluation and owner requirements [49], which helps to increase the willingness of construction units to engage in green innovation. Secondly, from the perspective of information integration and sharing, unlike traditional innovation, green innovation involves highly integrated information on energy saving, pollution prevention, waste utilization, and clean production. The BIM-based Green 2.0 system enables stakeholders such as the government, participating organizations, and housing tenants to comment on and share their views on building design. The system integrates an energy analysis software that allows different products to be selected from the stakeholder catalog and evaluates the impact of each product on energy consumption [50]. It can be seen that BIM can break through information barriers, realize the collection, integration, and sharing of information related to green and low-carbon environmental protection, help enterprises to comprehensively grasp the information required for green innovation, and provide technical support for the smooth transmission and efficient sharing of information to reduce the risk of green innovation and promote the output of green innovation. Therefore, the following hypothesis is proposed in this paper.

H2: *BIM applications have a positive effect on green innovation.*

2.3. The Mediating Role of Green Innovation

In terms of project economic performance, by using new or improved production processes in the implementation of green innovation, enterprises can not only reduce material inputs in production and manufacturing and other processes, realize intensive production, and achieve cost minimization, but also enhance production capacity, increase the input–output rate, and improve economic performance [51]. Li et al. (2022) found that when there is insufficient technological innovation and enterprises do not participate in serious polluting business activities, green innovation negatively affects economic performance; when there is technological process upgrading and enterprises participate in serious polluting business activities, green innovation significantly promotes economic performance and stimulates environmental performance improvement [52]. This condition of green innovation to promote the economic performance of projects fits well with the construction industry. Meanwhile, green innovation can improve market competitiveness and form a differentiation advantage, helping enterprises to achieve higher market performance and improving economic performance [53]. Additionally, there is a technological spillover effect of green innovation; i.e., a high rate of green innovation in a particular region will prompt companies in the same region to conduct green innovation [54], which reduces the resistance of external stakeholders and the cost of environmental violations, avoids additional economic expenditures, and improves economic performance.

In terms of project environmental performance, theoretically, the development, operation, and updating of green technologies can reduce the emissions of wastewater, exhaust, and solid waste from enterprises, thereby suppressing regional environmental pollution [55]. In practice, firms engaging in green innovation can, to a large extent, contribute to significant improvements in environmental performance, and many studies have demonstrated that firms engaged in green innovation have improved performance in terms of their competitive advantage and green image [46,56,57]. Taken together, technological innovations can minimize environmental burdens within the boundaries of industrial ecosystems, not only by improving the efficiency of energy-waste treatment, but also by controlling carbon dioxide emissions. [58]. In China's economic development and industrialization process, technological innovation usually improves the quality of the ecological environment and reduces the degree of environmental pollution, which is mainly manifested in the impact of production technology and governance technology on environmental pollution. First, in terms of source prevention, green innovation can greatly promote renewable energy consumption, reduce carbon dioxide emissions, and mitigate climate change [59]. Second, in terms of production management, green innovation will help construction enterprises to develop green materials and processes, such as new wall materials and automatic painting robots, which will improve resource utilization and reduce resource waste during on-site construction, thereby alleviating resource constraints; meanwhile, the adoption of green innovation has the potential to reduce pollution, improve the disposal of hazardous and toxic wastes, and realize clean production [51]. Finally, in terms of end-of-pipe management, green innovation by construction enterprises can recycle or harmlessly treat construction waste and reduce the environmental load. Therefore, this paper hypothesizes that conducting BIM applications is conducive to improving the level of green innovation of construction firms and further enhancing the project's environmental performance.

In terms of the project's social performance, since the introduction of the low-carbon economy, the public has paid attention to low energy consumption and low carbon emissions, and enterprises, as the main economic pillars of society, have undertaken the biggest low-carbon tasks. Enterprises should introduce environmental protection concepts into consumer-oriented products, extend corporate responsibility to social terminals, manifest the corporate image and mission of the courage to embrace environmental responsibility and environmental friendliness, and promote social responsibility performance. The work of Baeshen et al. (2022) on Saudi Arabian manufacturing firms also suggests that green innovation will improve the firm's business image, thereby improving the firm's social performance [60].

To summarize, green innovation has provided a significant contribution to project sustainability performance, while the realization of project sustainability performance depends on resources [61]. From the "resource–capability–growth" perspective of the resource-based view, capability is the key bridge between resources and project sustainability performance. By upgrading the level of digital technology application and integrating green-related resources, enterprises can help to improve their green innovation capability and, thus, enhance their sustainable development capability. Therefore, the higher the level of BIM application is, the more conducive it is to the construction enterprises in green building to conduct green innovation and, thus, improve project sustainability performance. Thus, the following hypothesis is proposed in this paper.

H3: *Green innovation plays a role as a mediator between BIM application and project sustainability performance.*

2.4. The Moderating Role of Institutional Pressures

Green innovation provides an effective and indispensable solution for handling changing environments and increasing institutional pressures; according to Ghisetti et al. (2015), green innovation is very different from non-green innovation, and technological facilitation alone does not provide sufficient incentives for firms to develop green innovation [62]. Therefore, it is necessary to construct an institutional environment that exerts pressure on firms, and the "push–pull effect" of institutional pressures is a driving force to promote green innovation [63]. Porter et al. put forward the "Porter's hypothesis", which points out that a strict but properly designed system can force the industry to innovate, thus enhancing resource efficiency and productivity, and the additional expenditure generated by compliance production can be offset by the benefits brought by innovation [64].

Relevant policies issued by the government affect the strategy formulation and development planning of enterprises, which will result in green innovation attempts in the production process to meet the government's requirements and obtain external recognition, thereby ensuring the smooth production and operation of enterprises and long-term sustainable development [65]. However, due to the limited internal resources and knowledge of enterprises, when enterprises feel strong institutional pressures, they will not only actively exploit external knowledge resources but also tend to invest more resources and knowledge in green innovation activities that alleviate these institutional pressures to prevent negative consequences (e.g., administrative penalties, etc.). For instance, the stronger the incentive for heavy-polluting industries to reduce pollution emissions per unit of output by increasing investment in technological research and development, the higher the intensity of institutional pressures; in this case, some enterprises will exit due to difficulties in meeting the standards; i.e., the number of enterprises in the regulated industry will decrease. Meanwhile, the market concentration is gradually increasing, and the survived enterprises will pay more attention to technological innovation [66]. Therefore, the larger the institutional pressures, the greater the motivation of enterprises to obtain external spillover resources and knowledge, the higher the utilization efficiency, and the more they will invest knowledge resources in green innovation activities.

Under weak institutional pressures, the stronger the incentive for enterprises to obtain an economic output to offset the rising cost of institutional pressures by increasing the input of production factors, the lower the enthusiasm and initiative of enterprises in pollution control; in this case, the increase in the input of production factors and the passive investment in pollution control will reduce the enterprise's investment in technological innovation, and, with the increase in the level of institutional pressures, the crowding-out effect becomes more prominent, and the enterprise's technological innovation capacity declines due to insufficient investment in R&D [67]. Additionally, because the green innovation process has a high level of uncertainty and certain requirements for the resources and capabilities of enterprises, it is risky and challenging for enterprises to truly implement the relevant policies in the production and operation process [68]. Therefore, this paper hypothesizes that, under weak institutional pressures, firms will have fewer negative consequences for not engaging in pollution control, and they usually take symbolic and strategic measures to handle the institutional pressures to gain external legitimacy. Thus, the following hypothesis is proposed in this paper.

H4: *Institutional pressures play a positive moderating role in BIM application and green innovation*.

When firms face a higher level of environmental regulation, their environmental behavior will receive more attention from the government. In the context of vigorously developing the digitalization and greening of the construction industry, construction firms tend to invest digital resources in green innovation practices to gain organizational legitimacy, more resources, and stronger viability [69]. This promotes firms to more actively utilize digital technologies to seek green innovation to obey and satisfy relevant environmental regulations and further improve sustainability performance. Secondly, since a heavily polluting enterprise that receives media and public attention may be more inclined to safeguard its reputation, it will actively utilize digital technology applications to pursue green innovation and respond to external normative institutional pressures, thereby gaining social legitimacy recognition and improving its image and economic performance. Finally, existing research has pointed out that incumbent firms may be severely challenged by "disruptive" innovations of new entrants, and, to achieve sustainable economic, environmental, and social performance, incumbent firms may engage in technological and knowledge innovations under the influence of new entrants [70]. Thus, this paper hypothesizes that, at a higher level of institutional pressures, there may be a larger impact of BIM on project sustainability performance through green innovation. Therefore, the following hypothesis is proposed in this paper.

H5: *Institutional pressures play a moderated mediating role in the impact of BIM applications on project sustainability performance through green innovation*.

Based on the above theoretical analysis, this study constructs a conceptual model, as shown in Figure 1.

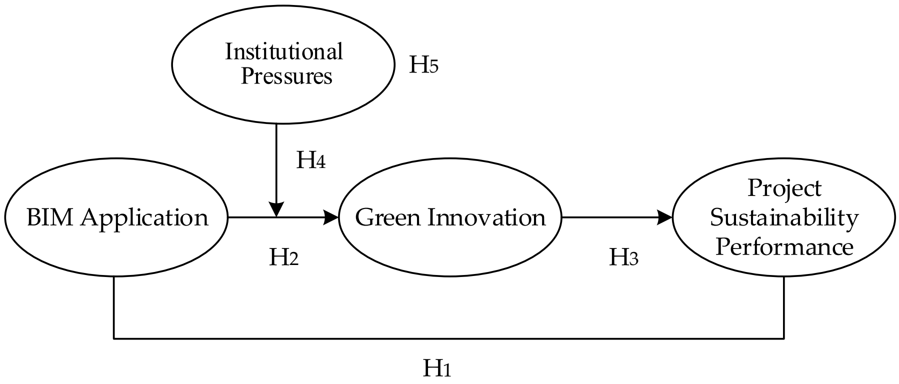

Figure 1. Conceptual model.

3. Materials and Methods

3.1. The Workflow of Method

The workflow of this research method is shown in Figure 2, which includes five subsections: theoretical analysis, literature review, questionnaires and data, data analysis and results, and discussion.

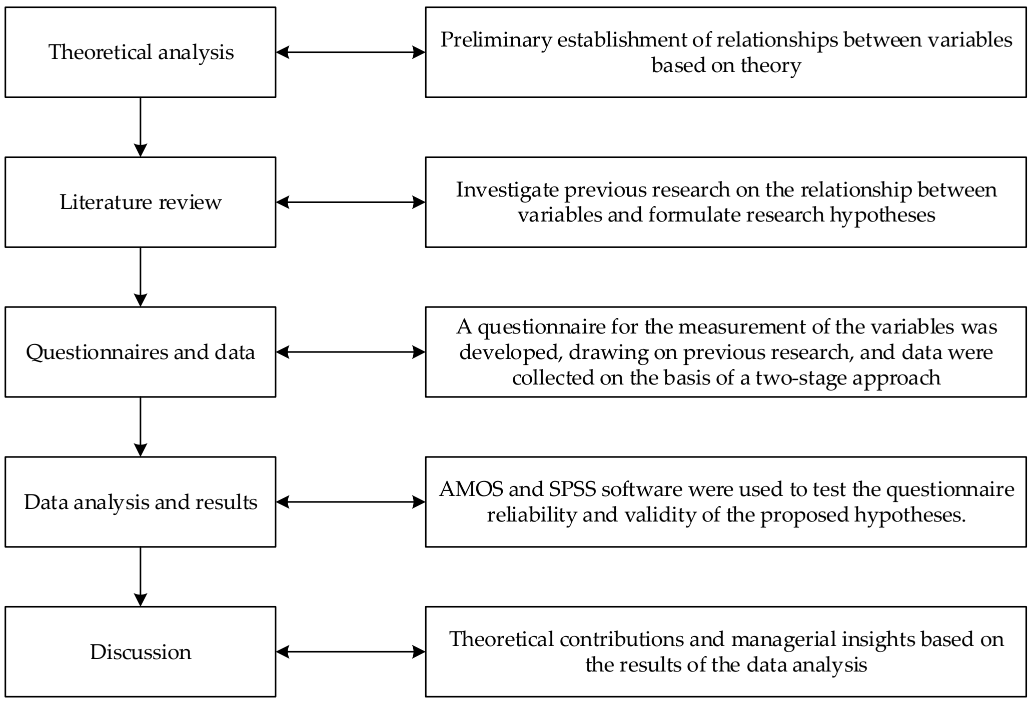

Figure 2. The workflow of method.

3.2. Research Sample

This study was conducted through two stages of data collection, the subjects were mainly concentrated in Jinan, Qingdao, Guangzhou, Shenzhen, and Beijing, and the main research subjects were the employees of electric power construction enterprises and their supervisors. Data collection was performed by asking two research assistants to assist in distributing the questionnaires. In September 2023, a total of 689 subjects were given questionnaires mainly to evaluate BIM application, green innovation, institutional pressures, and the subjects' personal basic information. After eliminating unqualified questionnaires (the answers showed a "Z" pattern) and incomplete questionnaires (there were missing answers), a total of 612 valid questionnaires were obtained, with an effective recovery rate of 88.82%. One month after the interval, i.e., after the monthly assessment of the subject enterprise, in October 2023, the questionnaires were distributed to the subjects who had effectively filled in the questionnaire for the first time, mainly to evaluate the project sustainability performance, and, after eliminating unqualified and incomplete questionnaires, 449 valid questionnaires were obtained, and the final questionnaire validity recovery rate was 65.17%.

Among the subjects, 54.3% were male subjects and 45.1% were female subjects; the age of the subjects was mainly between 30–40 years old, accounting for 47.9%, while the age group of 20–30 years old accounted for 29.2%; in terms of educational attainment, the subjects mainly held Bachelor's degree, accounting for 55.5%, followed by specialized education accounting for 19.6%, postgraduate education accounting for 18.7%, and the others accounting for 6.2%.

3.3. Measurement of Variables

The variables in this study have many established scales, based on which the formulation of the questions was appropriately revised to fit the theme and context of the construction business (as shown in Table 1). Meanwhile, the subjects were asked to select a recently completed project applying BIM to answer the questions, thereby improving the accuracy of memorization. All question items were measured using a 5-point Likert scale method (1 = "Strongly Disagree", 5 = "Strongly Agree").

Table 1. Variables and items.

Variables	Items
BIM application	The program has the technical knowledge resources to develop and apply BIM.
	The project has specialized BIM technicians.
	The functionality of the BIM model meets the needs of the project.
	The project developed a detailed plan for the application of BIM technology.
Project sustainability performance	In a recent project where BIM technology has been applied, the cost of the project has been reduced.
	In a recent project where BIM technology has been applied, the duration of the project has been reduced.
	In a recent project where BIM technology has been applied, project stakeholder satisfaction has increased.
	In a recent project where BIM technology has been applied, project labor productivity and efficiency have increased.
	In a recent project where BIM technology has been applied, the experience of the implementation of this project has been promoted.
Green innovation	Green innovations help buildings lead the industry in energy efficiency and emissions reduction.
	Green innovation helps companies improve their market competitiveness.
	Green innovation helps companies build a good social image.
	Green innovation helps companies to continuously research and develop green technologies and new products.
	Green innovations help companies continuously improve their production and construction processes to achieve higher green building ratings.
Institutional pressures	The government has established strict laws and regulations on link protection.
	Green innovation in the region or in peer companies has a profound impact on the organization.
	The public will report production and business activities that damage the environment.

(1) Explained variables

The explanatory variable is project sustainability performance, which draws on the study conducted by Zheng et al. (2017). The variable can be divided into three dimensions: economic performance, environmental performance, and social performance, with a total of five question items [71]. A typical question item is "In projects where BIM has been applied recently, the satisfaction of the project's stakeholders has improved". The Cronbach's alpha coefficient for this scale is 0.898.

(2) Explanatory variable

The explanatory variable is BIM application, which draws on the study conducted by Zhang et al. (2022) on measuring BIM application with four question items [72]. A typical item is "The project has a detailed plan for BIM application". The Cronbach's alpha coefficient for this scale is 0.919.

(3) Mediating variable

The mediating variable is green innovation, which draws on the scale developed by Jansen et al. (2006) [73] and Chan et al. (2005) [74], with five items. A typical item is "Green innovations have helped the building to lead the industry in energy efficiency and emission reduction". The Cronbach's alpha coefficient for this scale is 0.883.

(4) Moderating variable

The moderating variable is institutional pressures, which draws on the scale developed by Wang et al. (2023) [75] and consists of three items. A typical item is "The government has enacted strict laws and regulations on environmental protection". The Cronbach's alpha coefficient of this scale is 0.864.

The reliability coefficients of the above scales are all greater than the statistically recommended standard, i.e., $\alpha > 0.7$, indicating that the above scales have high measurement reliability. Referring to previous related studies on project sustainability performance, gender, age, and education level were used as control variables in this study.

4. Results

4.1. Validation Factor Analysis

To investigate the discriminant validity between the variables, this study utilized AMOS 23.0 to carry out a validation factor analysis of the measured variables (BIM application, green innovation, institutional pressures, and project sustainability performance). The results of the validation factors are listed in Table 2. The study of Hu and Bentler et al. (1999) [76] shows that a model has a good fit if χ^2/df takes the value of 1 to 5, RMSEA is less than 0.08, and GFI, CFI, NFI, etc. are all greater than 0.9. According to this, the hypothesized factor model (Model 1: BIM application, green innovation, institutional pressures, and project sustainability performance) has a good fit, with χ^2/df = 3.379, GFI = 0.909, CFI = 0.953, NFI = 0.934, and RMSEA = 0.063, which all satisfy the validation statistical criteria; however, the other replaceable nested models (Models 2–5) have significantly worse fit, and none of them satisfy the statistical criteria. Additionally, the hypothesized four-factor model is significantly better than the other replaceable nested models (Models 2–5) and has better discriminant validity.

Table 2. Validation factor analysis.

Model	χ^2/df(df)	GFI	CFI	NFI	RMSEA
Model 1: BA; GI; IP; PSP	3.379 (113)	0.909	0.953	0.934	0.063
Model 2: BA; GI + IP; PSP	6.403 (116)	0.819	0.890	0.872	0.110
Model 3: BA + GI; IP; PSP	11.991 (116)	0.684	0.775	0.776	0.157
Model 4: BA + GI + IP; PSP	14.691 (118)	0.642	0.715	0.702	0.175
Model 5: BA + GI + IP + PSP	15.963 (119)	0.629	0.686	0.673	0.183

Notes: BA denotes BIM application; GI denotes green innovation; IP denotes institutional pressures; PSP denotes project sustainability performance; "+" denotes the combination of variables.

4.2. Descriptive Statistics and Correlation Analysis

To reduce the common method bias, this study used the anonymous completion of the questionnaire while adopting two stages of data collection (with a time interval of 1 month) to minimize the impact of common method bias on the overall model. Moreover, this study employed the Harman one-factor test to investigate the degree of common method bias in the data. The results of the data showed that four common factors were extracted, and the cumulative total variance explained was 71.022%, of which the variance explained by the largest factor extracted was 31.023%, which was lower than the threshold value of 50%. Therefore, the common method bias fell within acceptable limits and did not affect the relationship of the variables tested.

Table 3 shows the mean, standard deviation, and correlation coefficient of each variable. As listed in Table 3, BIM application has a significant positive correlation with green innovation (r = 0.40, $p < 0.01$), institutional pressures (r = 0.44, $p < 0.01$), and PSP (r = 0.42, $p < 0.01$); meanwhile, green innovation has a significant positive correlation with project sustainability performance (r = 0.43, $p < 0.01$), which provides a preliminary research basis for the subsequent hypothesis testing.

Table 3. Means, standard deviations, and correlations.

	1	**2**	**3**	**4**	**5**	**6**	**7**
1. Gender	1						
2. Age	−0.12	1					
3. Education	0.08	0.11	1				
4. BA	−0.06	−0.15	0.05	1			
5. GI	−0.06	0.01	0.05	0.40 **	1		
6. IP	−0.04	−0.16	−0.03	0.44 **	0.42 **	1	
7. PSP	−0.03	−0.04	0.03	0.42 **	0.79 **	0.43 ***	1
Mean	1.54	3.44	2.87	3.30	3.98	3.41	3.97
Std	0.50	1.43	0.78	0.82	0.50	0.80	0.53

Notes: ** indicates significance at the 0.05 level, and *** indicates significance at the 0.01 level.

4.3. Hypothesis Testing

Main effects test: This study utilized SPSS 22.0 statistical analysis software to conduct hierarchical regression analysis among variables, and the analysis results are presented in Table 4. Model 4 shows that BIM application has a significant positive effect on project sustainability performance ($\beta = 0.28$, $p < 0.01$), so Hypothesis 1 is verified.

Table 4. Hierarchical regression results of main effect and mediating effect.

Variables	**GI**			**PSP**	
	M1	**M2**	**M3**	**M4**	**M5**
Control variables					
Gender	−0.07	−0.04	−0.05	−0.01	0.02
Age	−0.01	0.02	−0.02	0.01	−0.01
Education	0.04	0.05	0.03	0.03	−0.01
Independent variable					
BA		0.25 **		0.28 **	0.08 **
Mediator					
GI					0.79 **
R^2	0.01	0.17	0.01	0.17	0.64
ΔR^2	0.01	0.16 **	0.01	0.16 **	0.47 **
F	1.14	23.28 **	0.70	24.59 **	159.31 **

Notes: ** $p < 0.01$; N = 449.

Mediating effect test: This study tests the mediating effect with reference to the study of Baron and Kenn [77]. As shown in Model 2, BIM application has a significant positive effect on green innovation ($\beta = 0.25$, $p < 0.01$), so Hypothesis 2 is verified. Model 5 adds the mediator variable (green innovation), and the results indicate that, compared with Model 4, the coefficient of influence of BIM application on project sustainability performance decreases (β decreases from 0.28 to 0.08, $p < 0.01$), but green innovation still has a significant positive influence on project sustainability performance ($\beta = 0.79$, $p < 0.01$). This demonstrates that green innovation plays a mediating role in the relationship between BIM application and project sustainability performance.

To test the robustness of the mediating effect, the Bootstrap method developed by Preacher et al. (2010) [78] was employed to verify the mediating effect again, and the number of random samples was set to 5000. The results indicate that the mediating effect value of green innovation is 0.1960, with a 95% confidence interval of [0.1403, 0.2507]; meanwhile, the confidence interval does not contain 0, indicating that BIM application has a significant indirect effect on project sustainability performance through green innovation, so Hypothesis 3 is verified.

Moderating effect analysis: In this study, BIM application and institutional pressures are centered to avoid the problem of multicollinearity, and then the moderating effect of institutional pressures is tested through hierarchical multiple regression. As shown in Table 5, Model 9 shows that the interaction term between BIM application and institutional pressures has a significant effect on green innovation ($\beta = 0.06$, $p < 0.01$), indicating that institutional pressures play a positive moderating role between the relationship of BIM application and green innovation, so Hypothesis 4 is verified.

Table 5. Hierarchical regression results of moderating effects.

Variables	**GI**			
	M6	**M7**	**M8**	**M9**
Control variables				
Gender	−0.07	−0.04	−0.04	−0.03
Age	−0.01	0.02	0.02	0.02
Education	0.05	0.05	0.04	0.03
Independent variable				
BA		0.25 **	0.05 **	0.02 **
Moderator				
IP			0.20 **	0.22 **
Interaction				
BA * IP				0.06 **
R^2	0.01	0.17	0.19	0.21
ΔR^2	0.01	0.16 **	0.02 **	0.02 **
F	1.14	23.28 **	20.81 **	20.06 **

Notes: * $p < 0.05$, ** $p < 0.01$.

Moderated mediation: The moderated mediation effect was tested by the SPSS Process macro program, where the means of institutional pressures plus or minus one standard deviation were divided into three groups of high, medium, and low to compare the mediation effect of green innovation under different levels of institutional pressures. The results are presented in Table 6, and it can be seen that the mediating effect of green innovation in the relationship between BIM application and project sustainability performance is not significant under low institutional pressures (95% confidence interval of [−0.2077, 0.1312]), but the mediating effect is significant under high institutional pressures (95% confidence interval of [0.0971, 0.2098]), with an effect value of 0.0540, indicating that the higher the institutional pressures, the stronger the indirect effect of BIM application on project sustainability performance through green innovation, so Hypothesis 5 is verified.

Table 6. The moderated mediation effect.

	Effect	**SE**	**Boot LLCI**	**Boot ULCI**
Low IP	−0.0405	0.0845	−0.2077	0.1312
Medium IP	0.0304	0.0775	−0.1218	0.1888
High IP	0.0540	0.0768	0.0971	0.2098
IP	Index	SE	Boot LLCI	Boot ULCI
	0.0709	0.0252	0.0217	0.1191

5. Discussion

5.1. Theoretical Contribution

Based on the resource-based view and institutional theory, this paper studies the relationship between BIM application and project sustainability performance for power grid engineering projects, and the main theoretical contributions are summarized as follows:

(1) The BIM literature mainly focuses on stakeholders and project economic efficiency, and the research level is limited to project resources and project performance, ignoring the impact of the capability level. In this case, it is difficult to identify and understand the influencing factors at other levels of project sustainability performance, and the performance and value of project sustainability performance at each level cannot be recognized effectively. Therefore, this paper addresses this issue and conducts a preliminary exploration of the relationship between BIM application and project sustainability performance in the context of China's power grid projects. The study results expand and supplement the influencing factors of project sustainability performance and further enrich the impact effect of sustainable-development-oriented BIM in the context of China's power grid projects.

(2) Based on the resource-based view and existing studies, this paper investigates the mediating effect of green innovation on the relationship between BIM application and project sustainability performance, and it is confirmed that BIM application indirectly affects project sustainability performance as a distal outcome through green innovation as a proximal outcome. This helps to further clarify the influencing path of BIM application on project sustainability performance, which is of great theoretical significance, and it also verifies and expands the theoretical explanation of the resource-based view on the relationship between BIM application and project sustainability performance.

(3) Based on the institutional theory, this paper incorporates institutional pressures as an institutional environment factor into the study of the relationship between BIM application and green innovation. The study results demonstrate that institutional pressures positively moderate the relationship between BIM application and project sustainability performance, and that a higher level of institutional pressure is an external driver to stimulate enterprises to further invest digital resources in green innovation practices. Previous studies have shown that institutional pressure may have a U-shaped relationship on the total technological innovation level of enterprises, and that the investment in green innovation limits the increase of the overall technological innovation level before the "inflection point" occurs, but, for the improvement of green innovation, institutional pressure and green innovation should show a positive correlation, and, with the increase of institutional pressure, the level of green innovation is increasing. As institutional pressure rises, the level of green innovation rises. Furthermore, the mediating role of green innovation between BIM application and project sustainability performance depends on the level of institutional pressures. This helps to expand the application scope of the institutional theory, clarify the boundary conditions under which the BIM application affects green innovation, and, thus, enhance the contextualization of the relationship between the two studies.

5.2. Practical Insights

This study provides the following management insights for project stakeholders:

(1) Project sustainability has become a research hotspot in today's construction industry in China and even the world, and it is an important driving force for successful project delivery. Therefore, improving project sustainability performance has become an important goal for construction organizations and stakeholders. In this paper, it is found that BIM application has a positive impact on project sustainability performance. This suggests that construction companies need to focus on and continuously improve the level of BIM application and increase the depth and breadth of BIM application for the whole project life cycle. For instance, using BIM to establish a 3D model of a

building for 3D visualization can help the design team better understand the shape and features of the building to achieve a more accurate design; BIM is utilized in the design phase to detect component collision clashes during construction, thus avoiding modifications and re-work and decreasing waste and costs; using BIM to construct visualization models and perform simulations can better communicate the concept of sustainable design and construction to all stakeholders and promote their participation and understanding.

(2) This paper also found that BIM application can affect project sustainability performance through green innovation. It indicates that enterprises that have applied BIM need to consolidate the foundation of BIM application, introduce a new generation of information technology into the project, increase the breadth and depth of BIM application, integrate green environmental-protection-related knowledge and information and technology resources, improve green innovation capabilities, and strive to promote the transformation of green innovation results, thereby obtaining green core competitiveness and realizing sustainable development—for example, how to apply BIM to the analysis of project and building energy consumption, how to improve the efficiency of facility management, and how to promote collaboration among different professions.

(3) Institutional pressures have a significant moderating effect on the relationship between BIM application and green innovation, and a high level of institutional pressures strengthens the mediating role of green innovation between BIM application and project sustainability performance. This indicates that local governments and the public should take necessary measures to create regulatory and normative pressures. On the one hand, environmental laws and regulations should be strengthened and improved, including tightening the targets for energy consumption and waste treatment, increasing the amount of investment in industrial pollution control in the region, and exploiting the innovation-driven role of environmental regulation. On the other hand, it needs to increase government support for enterprises and promote the active use of digital technology to empower green innovation through the development and implementation of green incentives, such as the issuance of subsidies, loans, and tax incentives related to green innovation. Additionally, industry associations need to guide enterprises in healthy competition, stimulate the herd effect, and guide enterprises to improve their green innovation capabilities by applying digital technologies.

6. Conclusions and Limitations

6.1. Conclusions

This study utilizes the resource-based view and institutional theory to construct a theoretical framework of the relationship between BIM application, green innovation, and project sustainability performance. The working experiences of 449 members of personnel of electric power construction enterprises are used as the research data to explore the impact of BIM application on project sustainability performance, the mediating role of green innovation, and the moderating role of institutional pressure. Based on the empirical results, the following conclusions are drawn.

(1) BIM application has a positive impact on project sustainability performance, which not only helps to co-ordinate the project resources and stakeholders, but also improves the level of scientific decision-making and work efficiency. In addition, through BIM application promoting resource conservation, we can optimize the efficiency of the environmental management of the whole process of the project, so as to realize the economic benefits and environmental and social benefits that go hand in hand, resulting in a natural harmonious coexistence with the project.

(2) Green innovation plays a mediating role between BIM application and project sustainability performance. By improving the level of BIM application, construction firms can better break down the information barriers between stakeholders, and further

integrate green resources to improve their green innovation capability. Moreover, through the implementation of green innovation, not only can the enterprise establish an environmentally friendly image, but also obtain green core competitiveness and improve energy efficiency. And, thus, the construction enterprise can enhance the performance of environmental and social responsibility, and, ultimately, realize the sustainable development of carbon neutrality and carbon peak.

(3) Institutional pressures play a moderating role in the relationship between BIM application and green innovation. The green innovation behavior of construction enterprises is influenced by the institutional environment where they are located, so the institutional pressure is oriented to the innovation behavior of construction enterprises. Specifically: (1) Institutional pressures positively moderate the relationship between BIM application and green innovation, and a high level of institutional pressure means that the local government strongly promotes and supervises enterprises in carrying out the low-carbon transformation. (2) Institutional pressures positively moderate the mediating role of green innovation in the relationship between BIM application and project sustainability performance, and a high level of institutional pressures can motivate enterprises to seek out new changes and competitive advantages. In order to gain more legitimacy, resources, and viability, enterprises are motivated to carry out digital changes and are more willing to take their own initiatives and apply BIM to promote green innovation, thus further releasing the potential and value of BIM applications to empower green innovation.

6.2. Limitations and Prospects

The following shortcomings exist in this paper: (1) The research sample selected in this paper is the survey data of employees in the electric power construction industry, which does not involve other types of heavy-pollution projects, such as transportation, housing, or water conservancy. In the future, the research sample can be expanded to explore whether all types of heavy-pollution projects can promote green innovation through the application of BIM to enhance project sustainability performance, in order to enhance the universality of the research conclusions. (2) The measurement of the variables of digital technology application in the study is based on the survey data of employees, which are highly subjective. Future research can take the information generated objectively by enterprises as research data, such as “annual report of enterprises”, “statistical yearbook”, “CSR rating”, and “number of patent applications”. Future research can further refine the data to obtain more scientific quantitative methods and conclusions with wider applicability. (3) This study does not distinguish between different types of green innovations. Future research can further distinguish between green process innovation, green product innovation, or “light green” clean production technology and “dark green” end-of-pipe treatment technology, in order to obtain more detailed research conclusions.

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Glossary

Abridged	**Explanation**
BIM	Building information modeling
GIM	Grid information modeling
BA	BIM application
PSP	project sustainability performance
GI	Green innovation
IP	Institutional pressures

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