

Review

Challenge for Chinese BIM Software Extension Comparison with International BIM Development

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Abstract: This study provides an in-depth analysis of the current status of the promotion and application of BIM software in China, highlighting its differences from the international market. Chinese BIM software shows advantages in data security, cost-effectiveness, user habit adaptability, and localization standards, but faces challenges in terms of technological maturity and ecosystem development. By employing bibliometric methods and utilizing literature resources from CNKI and the Web of Science, the study offers a comprehensive analysis of the market and policy environment and proposes targeted recommendations. The study indicates that Chinese BIM software has significant advantages in enhancing data security and cost-effectiveness but lacks technological maturity and requires improvements in ecosystem development. User habits are crucial for the promotion of BIM software, and the localization and adaptability of the software need further enhancement. To promote the widespread application of BIM in the architecture, engineering, and construction (AEC) industries, a robust market mechanism needs to be established. The government should strengthen policy support and improve regulatory frameworks; software developers should enhance product functionality and work closely with users; and application enterprises should actively provide feedback to promote software improvements. Moreover, the introduction of reasonable capital and the collaboration between educational institutions and enterprises to cultivate professional talent are critical for the promotion and application of BIM technology. The research emphasizes that forming a cross-departmental joint mechanism to promote a virtuous cycle in the AEC market is key to achieving the widespread application of BIM technology. These measures can provide strong market impetus for the development of BIM software, accelerate the maturity and ecosystem construction of Chinese BIM software, and ultimately realize the comprehensive upgrading of informatization and digitization in the construction industry.

Keywords: BIM; market; development; diffusion; China; international



Citation: Wang, Y.; Zhao, B.; Nie, Y.; Jiang, L.; Zhang, X. Challenge for Chinese BIM Software Extension Comparison with International BIM Development. *Buildings* **2024**, *14*, 2239. <https://doi.org/10.3390/buildings14072239>

Academic Editors: Yasser Mohamed and Pramen P. Shrestha

Received: 12 June 2024

Revised: 27 June 2024

Accepted: 18 July 2024

Published: 20 July 2024



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1. Introduction

Building Information Modeling (BIM) stands as a transformative technology poised to revolutionize the Architecture, Engineering, Construction, and Operations (AECO) sector by redefining how buildings are conceived, designed, built, and maintained [1]. This technology emerges as a response to the pressing need for more sustainable practices within the AECO sector, which currently accounts for a significant portion of global energy consumption [2]. Consequently, the sector's daily operations produce numerous negative environmental impacts [3], necessitating urgent measures to reduce polluting emissions [4] and enhance energy efficiency across all stages of construction projects (materials, processes, equipment, buildings). BIM technology emerges as a key enabler in addressing these

challenges, offering immense potential to contribute to sustainable development goals from the design phase to the end-of-life phase [5].

In recent years, BIM has garnered significant attention within the construction and engineering industry, with its technological and managerial advantages identified as pivotal factors in the success of megaprojects [6]. This underscores the considerable demand for BIM as a strategic tool for project implementation. Researchers have extensively documented the benefits of BIM adoption from various perspectives, including its technological capabilities such as information storage, visualization, and simulation [7] as well as its transformative impact on project management methodologies.

BIM, as a carrier of building information, can fully utilize the value of data. Therefore, the combination of BIM with AI, industrial Internet, and other emerging industries can promote the upgrading of the construction industry. By combining with AI technology, the construction industry can become more intelligent; for example, the research [8] adopts an artificial intelligence method and takes the completion BIM model as input, which can improve the decision-making process to adopt energy efficiency measures. Research [9] investigates using supervised and unsupervised ML techniques, which is a technology in artificial intelligence, to deduce implicit knowledge and detect errors from BIM models. BIM technology can be combined with industrial Internet technology, which can form an Internet ecology of the whole lifecycle of buildings by using building information, demonstrating the advantages of informatization. Research [10] proposed the concept of enterprise BIM based on an internet-based platform, CDE, to promote better utilization of building information modeling throughout the entire lifecycle of buildings by enterprises.

The rapid development of China's construction industry and the urgent need for informatization call for localized BIM software solutions. Information security has become an essential part of national security, and the development of domestic BIM software is crucial for protecting sensitive information in construction projects [11]. This not only helps reduce reliance on foreign technology but also enhances the nation's competitiveness and influence in the field of construction informatization [12]. China is vast, and there are significant differences in building codes, cultural characteristics, and market demands across different regions. Localized BIM software can provide solutions that are better tailored to local conditions, thus better meeting these diverse needs [13].

The development of domestic BIM software will drive the growth of related software industries, including software development, technical consulting, and education and training, forming a complete industrial chain. This will create more employment opportunities and facilitate technological accumulation within the country [14]. Additionally, this aligns with national policy directions, helping to gain policy support and market promotion advantages [15]. With continuous technological advancements, domestic BIM software can respond more quickly to market changes and technological updates, providing users with the latest features and services [9]. Ultimately, domestic BIM software not only meets the needs of the domestic market but also has the potential to enter international markets, showcasing China's strength in construction informatization [10]. Furthermore, it enhances intellectual property protection, ensuring the legal rights of enterprises and users during usage.

Recognizing the inherent benefits of BIM, governments worldwide have mandated its adoption, propelling the global BIM market to projected values of US\$22.1 billion by 2030, with a compound annual growth rate (CAGR) of 16.3% [16]. However, despite these mandates and imperatives, AECO organizations exhibit varying levels of ambivalence regarding the benefits of BIM [17], particularly notable among small-to-medium enterprises (SMEs) [18]. This results in disparities in BIM adoption across different types and sizes of organizations, leading to inconsistencies in achieving performance gains [19]. Succar and Kassem outlined a two-phase adoption process for BIM technology, emphasizing the transformative impact of BIM on organizational practices [20]. Similarly, Papadonikolaki et al. noted adjustments in inter-organizational documentation to facilitate BIM adoption, indicating its interaction with organizations at an inter-organizational level [21].

This study first analyzes the differences between research and implementation through a literature review, offline surveys, and online questionnaires. It proposes strategies to enhance government policy support, improve regulatory framework development, strengthen software developers' product functionalities, and establish a collaborative mechanism for close cooperation with users. The main sections of the study include the current market status, policy environment analysis, user habit adaptation, the advantages of localization standards, and specific recommendations. The contribution of this study lies in providing practical suggestions for the development strategy of BIM software with Chinese characteristics and in offering systematic measures and pathways for the sustainable development of BIM technology in the construction industry.

2. Materials and Methods

2.1. Literature Review Strategy Based on Bibliometrics

This article employs a research method based on bibliometrics to conduct a literature review, ensuring the collection of a wide range of accurate literature and a rigorous and reliable analysis process. The study selected the CNKI (China National Knowledge Infrastructure) and Web of Science Core Collection as the primary sources of literature, as these two databases provide rich academic resources. In the search using CNKI, we used an advanced search strategy with "BIM software promotion" as the core keyword, covering various fields such as vocational education, market research, business economics, and architectural science and engineering. The search period ranged from 2013 to 2024, resulting in an initial retrieval of 491 articles. After meticulous data cleaning, deduplication, and preprocessing, we selected 437 articles for further in-depth analysis. The search using CNKI was completed on 22 January 2024. For the search using the Web of Science Core Collection, we utilized a comprehensive search expression combining "BIM" and related English synonyms such as "promotion" and "popularize" to enhance the comprehensiveness of the search. The search fields included engineering, architectural technology, computer science, etc., with the time span also set from 2013 to 2024. We retrieved 385 articles, and, after data cleaning and preprocessing, all the literature met the criteria with no invalid or irrelevant articles. Hence, all of the selected literature was included in the final analysis. The detailed steps and process of literature retrieval are shown in Figure 1. Through this systematic and scientific literature review method, we have laid a solid foundation for the depth and breadth of the research, ensuring the accuracy of the analysis and the depth of the discussion.

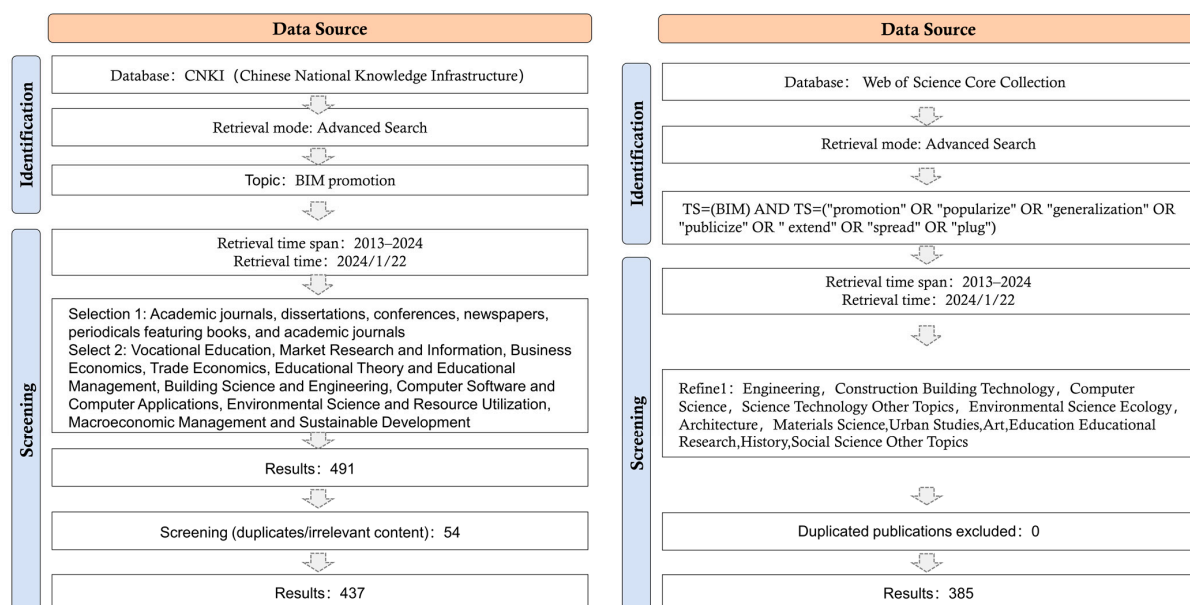


Figure 1. Literature Search Process.

2.2. Research Plan on the Promotion Policies of BIM Software in China

This research plan aims to deepen our understanding of the promotion status of BIM software in China. We intend to comprehensively collect policy documents and implementation details related to the promotion of BIM software in various provinces and cities in China, in order to thoroughly analyze the current promotion status. It is expected that this research plan will provide valuable decision-making references and a theoretical basis for policymakers, and promote the promotion and continuous innovation of BIM software in China.

The study selected major survey cities and relevant government departments, as well as related enterprises involved in the entire lifecycle of construction (including design firms, manufacturing companies, construction firms, etc.). Additionally, universities and academic associations were also included.

- (1) Targeted Interviews: Representative departments in provinces and cities such as Wuhan in Hubei, Changsha in Hunan, Guangzhou in Guangdong, and Chengdu in Sichuan were selected for group interviews.
- (2) Online Surveys: For application enterprises that could not be interviewed on-site, we expanded the research scope through online questionnaires to collect more extensive data. The research content covered the following aspects:
 - The situation of local housing and construction departments in formulating and implementing policies for promoting domestic BIM software.
 - The current status and needs of design units, construction units, production units, consulting units, and owner units in the application of BIM technology.
 - The role and contribution of academic groups and industry associations in promoting the development of BIM technology.

Among these, government departments and design/construction units have the highest proportions, accounting for 27.78%, 24.07%, and 18.52% of the total research subjects, respectively (Figure 2 shows the composition of units participating in on-site research).

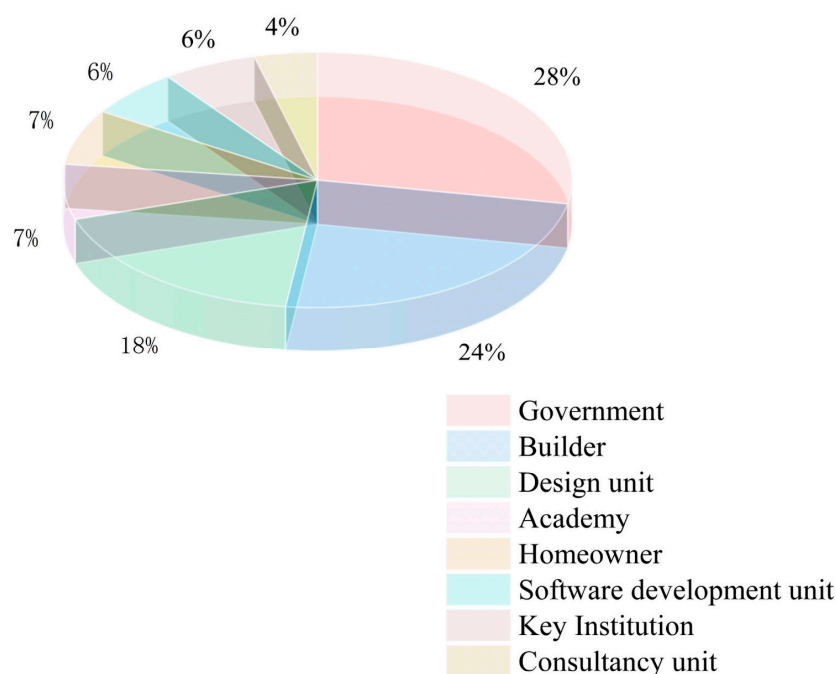


Figure 2. Composition of Units Participating in On-site Research.

3. Results

3.1. Overview of Existing Research

After conducting advanced searches on the CNKI and Web of Science databases, the search results indicate that the types of literature related to the promotion of BIM software

include academic journal articles, theses, conference papers, etc. The retrieved literature underwent strict screening and review processes, ensuring academic quality.

Figure 3a,b clearly depicts the annual trends in the number of publications in the field of BIM. From 2013 to 2018, the number of BIM-related publications on CNKI steadily increased in China, reaching a peak in 2018. However, since 2018, there has been a downward trend in the number of publications, decreasing to six articles by 2023. This technology has become oversaturated in China, leading to a phenomenon where scholars no longer invest as much effort into related research. This trend may indicate that BIM technology research in China is facing new challenges and transformations. In contrast, the Web of Science database shows that, internationally, the number of BIM-related publications steadily increased from 2013 to 2021, peaking in 2021. Although there has been a slight decrease afterward, the number still remains at a high level.

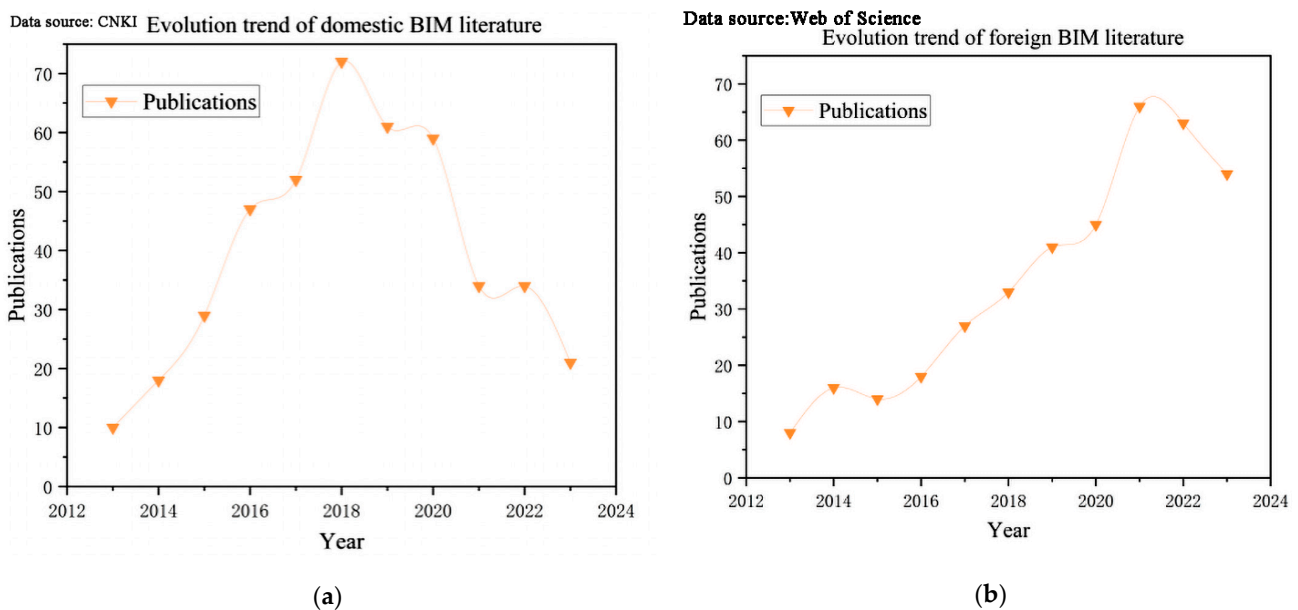


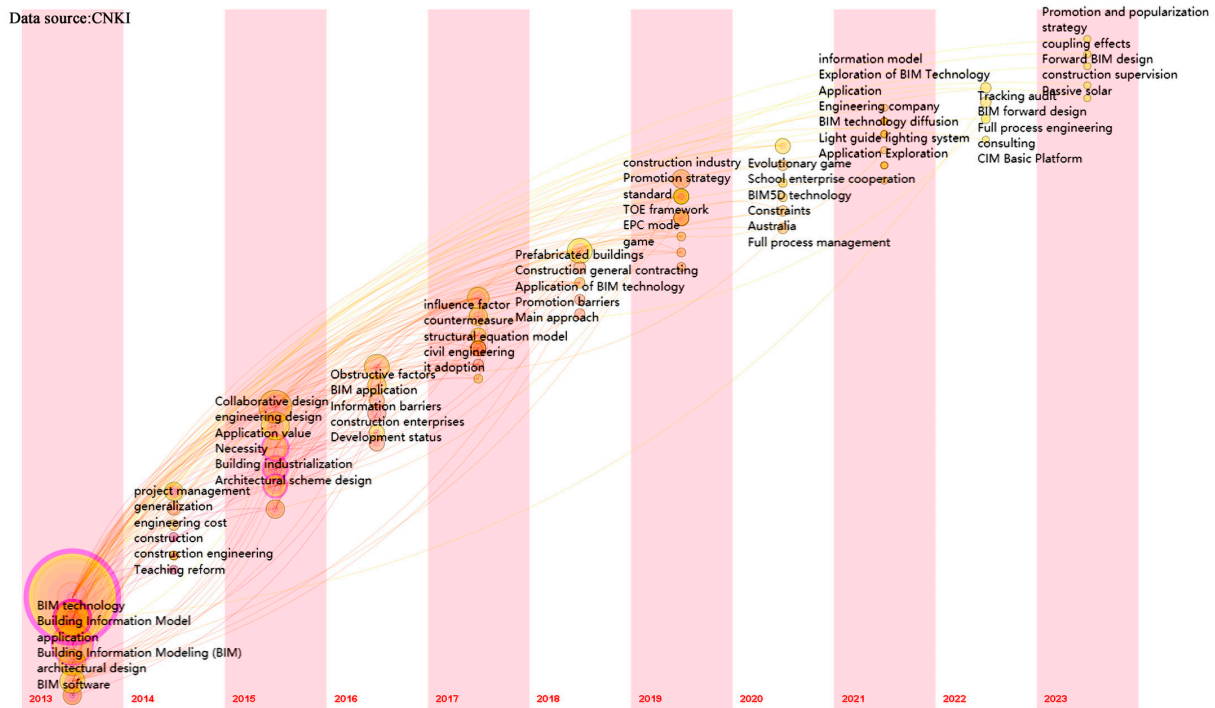
Figure 3. (a) Chinese Research Trends Chart. (b) International Research Trends Chart.

The comparison of international research [22,23] trends reveals that with the widespread application of BIM technology in China, research focus has shifted from basic theory and technical applications to more advanced areas [24]. Internationally, due to the openness and diversity of the academic environment, research on BIM continues to deepen [25], especially as developed countries have invested substantial research resources and funding, providing favorable conditions for BIM research.

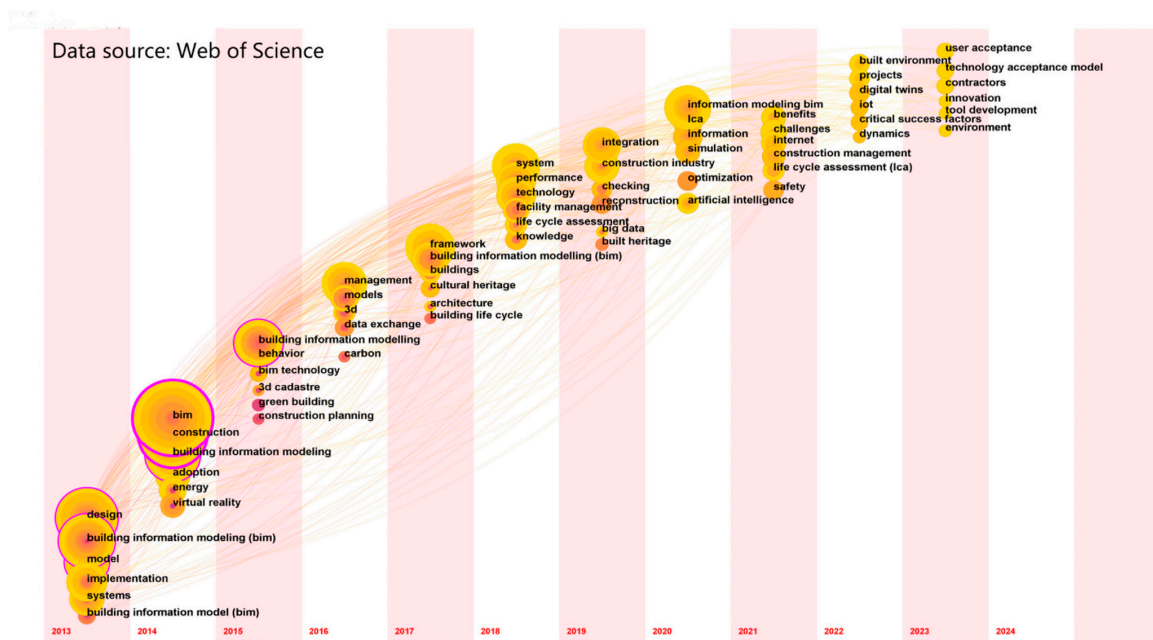
Figure 4 displays the number of publications by country on a world map, reflecting the differences in global attention and research intensity in the field of BIM across different regions. China leads with 144 publications, indicating a high level of focus on research related to BIM software. The United States follows closely with 36 publications, leveraging its market and technological advantages to conduct in-depth research in specific areas such as transportation data management and green building.

In the 2010s, BIM technology saw widespread application globally. It was especially active in Europe and North America, with the U.S. driven by market demand and industry associations, while the U.K. promoted BIM through mandatory government requirements. Nordic countries also made significant progress in BIM adoption [26]. In Asia, countries such as China, Japan, and South Korea have actively applied BIM technology. As shown in Figure 4, China leads in the number of publications. This is partly because China's technological development has not yet reached the industrial production stage, and BIM technology remains in the research phase, resulting in a higher volume of publications. Other regions, such as Australia, New Zealand, the Middle East, and Africa, are also

Figure 6a,b illustrates the evolving trends of keywords in the field of BIM over time. The research topics in the BIM field have expanded from traditional architectural design and construction project management to emerging areas such as automated modeling, digital twin technology, and lifecycle assessment. Through these analyses, we can observe that the application of BIM technology in the construction industry is becoming more diverse and profound. Researchers are continuously exploring new application scenarios and technological means, driving the development and progress of the construction industry.



(a)



(b)

Figure 6. (a) Time Zone Chart of BIM Keywords Evolution in CNKI. (b) Time Zone Chart of BIM Keywords Evolution in Web of Science.

Technology Acceptance Model in BIM promotion, emphasizing the importance of user acceptance for the widespread adoption of BIM.

The evolution of keywords reveals that, as a new technology, BIM is gradually permeating the construction industry, altering production relationships. The development of BIM technology has progressed from basic concepts to integration, intelligence, and widespread adoption. This process not only reflects system theory and dialectical materialism in philosophy but also embodies innovation diffusion theory and cost-benefit analysis in economics [40]. Through theoretical review, it is found that BIM itself does not have related theories and has not formed its own theoretical framework; instead, it relies on theories related to management and philosophy.

The application of BIM technology has not only improved upon issues that traditional design software may overlook but also optimized the architectural structures within three-dimensional models. Additionally, the press has focused on researching Australian BIM standards and implementation policies, introducing the practices and applications of BIM projects in Australia. At the same time, small- and medium-sized enterprises (SMEs) and large enterprises face different challenges when adopting BIM. SMEs mainly encounter challenges related to funding, talent, and resistance to change, whereas large enterprises need to address issues such as complex organizational structures, technological diversity, and standardized processes. Furthermore, this study reveals that the decision of enterprises to adopt BIM technology is closely related to the value it generates. When data are regarded as an asset, enterprises of all sizes are more likely to utilize BIM technology.

International research institutions, by building extensive collaborative networks, have effectively integrated resources and experiences, injecting a strong driving force for the application and continuous development of BIM technology [41]. International research excels in cutting-edge directions of BIM technology application and technological innovation capabilities, such as 3D concrete printing and construction safety risk assessment. Meanwhile, the relatively smaller collaboration network among Chinese research institutions may limit the exchange of resources and experiences, affecting the depth and breadth of research. Nevertheless, Chinese research actively seeks to learn from international experiences, as evidenced by studies on Australian BIM standards and the application of BIM in the Sydney Opera House project, demonstrating Chinese research institutions' attention to international BIM development trends and efforts to apply international experiences to local practices.

International research places more emphasis on technological innovation and international cooperation, while Chinese research focuses more on application exploration and drawing lessons from international experiences. Both complement each other and play important roles in the promotion and application of BIM technology [42]. As research on BIM technology continues to deepen, international institutions' collaboration and exchanges will play a positive role in driving the development of BIM technology.

As shown in Table 1, while some institutions in China have made research achievements in BIM, overall, there is still room for strengthening in-depth communication and collaboration between institutions, as evidenced by the relatively low intensity of literature collaboration. There are more research cooperation institutions abroad because BIM software has already established a collaborative ecosystem internationally. In China, such an ecosystem has not yet been established, and the number of cities promoting BIM is too few. Consequently, there is no collaboration network between enterprises, leading to a smaller cooperation network. First, BIM needs to be promoted and an ecosystem established, and only then can inter-enterprise cooperation be developed. Additionally, although some institutions have a substantial number of publications, the quality of their research outcomes does not seem to have correspondingly improved. Therefore, enhancing the research depth and breadth in the BIM field and improving research quality are crucial for promoting the application and development of BIM technology.

Table 1. Research Institution Information Table.

Number	Chinese Institution	Publication Quantity	Authors	Research Direction
1	Hong Kong Polytechnic University	9	Li X. Y.	Policy Intervention on BIM Technology Application
2	Southeast University	7	Yang L.	Automation Modeling of BIM Applications
3	Hong Kong University of Science and Technology	6	Lu W. S.	Automation Modeling of BIM Applications
4	China Academy of Building Research	5	Zongyi Zheng.	Architectural Design
5	University of Hong Kong	5	ChengJack C. P.	Automation Modeling of BIM Applications
6	Birmingham City University	5	Lu X. Z.	Building Information Modeling (BIM) and Virtual Reality (VR)
7	Xi'an Jiaotong-Liverpool University	5	He G. Y.	VDC/BIM Technology
8	Georgia Institute of Technology	5	Boyd D.	BIM Digitization
9	University of South Australia	5	Ugliotti F. M.	BIM Intelligent Data Modeling
10	Politecnico di Milano	5	Kim J.	BIM Building Element Classification
11	National BIM Industry Technology	4	Rong W.	BIM Project Practice and Application
12	School of Management, Shenyang	4	Hefeng T.	BIM Education
13	University of Naples Federico ii	4	Zhang S. J.	Automatic Application of Safety Rules to BIM
14	School of Civil Engineering and Architecture	3	Yungui L.	Application of BIM in the Construction Field
15	Liaoning Vocational College of	3	Guorong L.	Development of BIM
16	Swinburne University of Technology	2	Liang Z.	Evaluation of BIM Applications
17	Guangxi Vocational and Technical	2	Honguang Z.	Application of BIM Technology in Technical Teaching
18	Anhui Construction Engineering	2	Weihong Z.	Application of BIM Technology
19	School of Management Engineering	2	Zhansheng L.	Application of BIM Technology in Construction Projects
20	School of Civil Engineering	2	Ziru Z.	Application of BIM Technology

Research on the integration of Building Information Modeling (BIM) with sustainable construction and environmental aspects is relatively limited internationally. With the increasing importance of sustainable development, research that combines BIM technology with sustainability and environmental impact has become crucial. While BIM holds significant potential in material selection and building structure optimization, research in these areas has not received adequate attention [43]. However, some organizations have shown positive signs of integrating BIM technology with advanced technologies such as information modeling and virtual reality, enhancing the practical application of BIM technology [44].

In China, significant research achievements have been made in the application and development of BIM technology, but there is still a relative lack of research in policy-related fields that requires further strengthening. In the Chinese construction industry, the adoption and innovation support mechanisms for BIM technology are facing bottlenecks. Despite national and industry encouragement policies, the effects of promoting and applying BIM technology are not evident [45]. This may be because existing research mainly focuses on the practical application of BIM technology, lacking theoretical research on the adoption and promotion mechanisms of BIM technology.

Chen Yilin and others have constructed an analytical framework for BIM technology innovation support, intrinsic motivation, and innovative management behavior in the construction industry by integrating field dynamics theory and social cognitive theory, providing a new perspective for theoretical research to encourage management innovation in the construction industry. Wang Shaojun and others introduced the City Information Model (CIM) foundational platform and analyzed its construction principles, content,

and overall architecture, providing theoretical support for technology integration and platform development.

Overall, current research on BIM primarily focuses on technical applications and educational fields, with relatively less emphasis on theoretical research. Future research can continue to explore more theoretical frameworks and delve into the specific application of BIM in various fields and its impact on individuals. These studies not only offer valuable insights for addressing current issues in the application of BIM in China but also provide reference value for other countries facing similar challenges.

3.2. Software Supply Situation

In terms of software supply, according to market research data, Chinese BIM software is mainly divided into two categories: domestically controllable BIM software and BIM software developed based on international graphics engines. In recent years, with strong support from relevant policies in China, Chinese BIM software has made significant progress. However, the BIM software widely used in the market is mostly developed based on international graphics engines.

Currently, the United States maintains a dominant position in the global BIM market, with a market share of over 90% [46]. Software such as Autodesk’s Revit platform, Bentley’s Microstation, and France’s Dassault’s CATIA holds a significant share in the Chinese market. Autodesk’s Revit holds a monopoly position in the field of architecture; Bentley’s Microstation is mainly used in large building and infrastructure projects; and Dassault’s CATIA is primarily used for mechanical design and is commonly applied in curtain wall design and manufacturing in engineering projects.

The BIM software ecosystem panorama shown in Figure 8 illustrates the current status and future directions of global BIM software in different application stages and fields. This provides a macroscopic perspective and strategic planning for the development of Chinese BIM software, aiding in the comprehensive advancement of Chinese BIM software in areas such as technological research and development, market promotion, and industry applications.

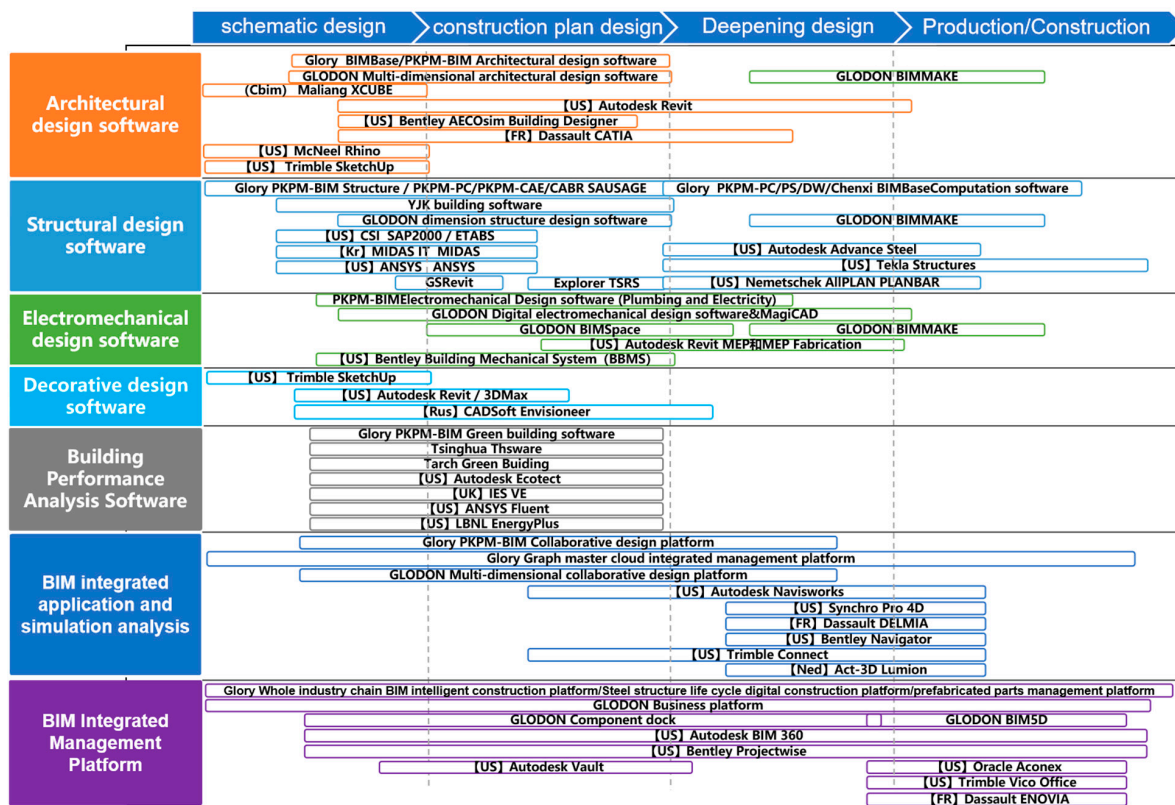


Figure 8. BIM Software Ecosystem Panorama.

Table 2 compares the comprehensive situation of Chinese BIM software with international BIM software. International software continues to dominate the market application, accounting for approximately 90%. Chinese BIM basic modeling software has essentially achieved over 80% of the functionalities of mature international BIM software within the scope of small- and medium-sized regular buildings.

Table 2. Research agency information.

Country	Representative	Advantages	Disadvantages
Chinese BIM Software	Guoli BIMBase, PKPM-BIM, PKPM-PC, Glodon Digital Tech Co., Ltd., BIMMAKE, C-True Malong, Hongye, Luban, Prime, Swirrl	Ensuring data security Operating habits that better meet the requirements of Chinese designers Embedded local standards within the software High level of support from the software company, with timely localization services Reasonable software pricing The software has reached a relatively mature stage of development, with significant advantages in modeling large-scale and complex buildings.	Low maturity level of the software, significant gaps in capabilities for complex buildings, large-scale projects, and irregular modeling. Insufficient development of the Chinese software ecosystem, resulting in the inability to bridge the gap with international achievements. The software has reached a mature stage, but lacks sufficient local support and resources, leading to slow functional updates. Due to core reasons, the software runs slowly and faces challenges in modeling irregular shapes.
International BIM Software	Autodesk, Bentley, Trimble, Dassault	There are a wide variety of software products available with a longstanding history of use, leading to a strong software ecosystem. The software demonstrates a relatively high level of maturity and offers a wide range of features.	Implementation of Chinese standards and regulations does not align with the habits of Chinese users, resulting in low levels of localization.

The issues with the supply of BIM software in China include a breakthrough in achieving “usable” functionality at various stages but not fully realizing the goal of being “user-friendly” in key areas such as parametric modeling. The main factors contributing to this situation include the urgent need for strengthened market applications and breakthroughs, numerous software enterprises but a lack of interconnected model data hindering collaboration, and a weak software ecosystem resulting in product iteration mainly relying on internal research and development efforts.

3.3. Software Application Market

As shown in Figure 9, the application life of BIM software in China is relatively short. 26.15% of enterprises have used Chinese BIM software for more than 5 years, while the majority of enterprises have used it for less than 5 years. Specifically, 23.67% of companies have used it for three to five years, and 22.61% have used it for one to two years. 9.19% of the units have not yet used Chinese BIM software [45], and 9.89% of the units have been in use for less than 1 year [47].

As shown in Figure 10, in terms of the number of application projects, 44.88% of the units use Chinese BIM software to complete projects between 1 and 10, 14.13% of the units have not yet applied projects, 11.31% of the units have applied projects between 10 and 20, and 8.48% of the units have applied projects between 20 and 30. 3.89% of the units are between 30 and 40 items, and 17.31% of the units are more than 40 items [48,49].

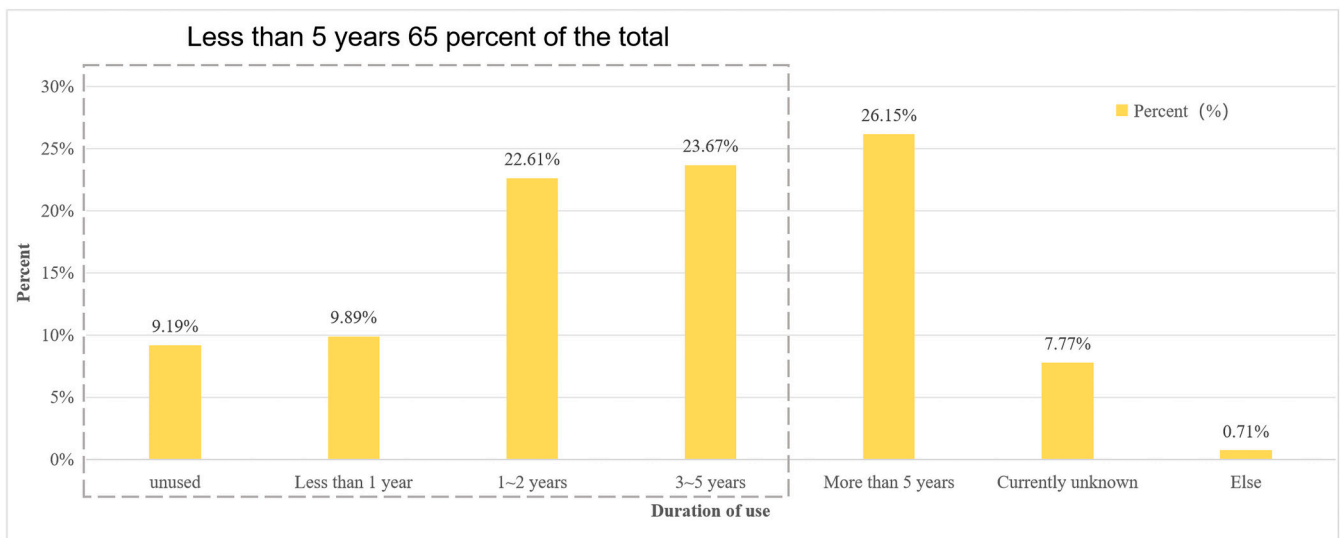


Figure 9. Duration of use for Chinese BIM software in investigated companies.

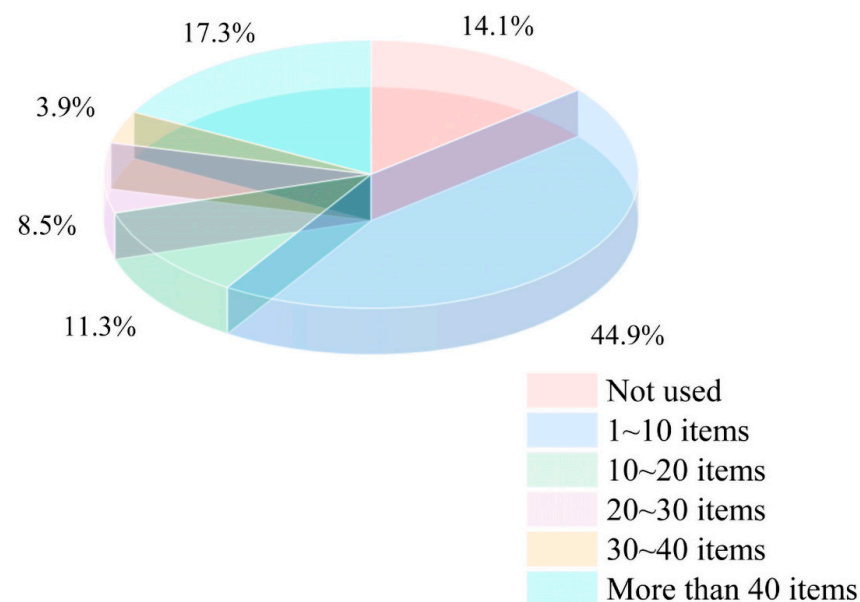


Figure 10. Application Status of BIM Software Projects in China.

This study conducted an online questionnaire survey to analyze the current development and challenges faced by BIM software in China, as shown in Figure 11. The results indicate that the main factors influencing the development of BIM software in China are user habits (62.54%), competition from similar products (33.92%), lack of market feedback (32.15%), and the impact of software piracy (31.44%). Industry professionals in China have limited awareness of Chinese BIM software [50], primarily due to inadequate promotion, limited demonstration effects, and an imperfect talent development system [51]. Additionally, companies are accustomed to the operational styles of international software, leading to resistance towards Chinese BIM software with different operation styles [22]. Therefore, key solutions to address these issues include enhancing the user-friendliness of Chinese BIM software [22], developing based on user habits, guiding the transformation of software based on international engines [23], and expanding the compatibility of Chinese software.

The survey results further indicate that government agencies, design firms, and construction enterprises are the main driving forces behind the development and application of BIM software in China, accounting for 27.78%, 24.07%, and 18.52% of the surveyed entities, respectively, as shown in Figure 12. The survey focuses on policy guidance, market

application management, government support, and ecosystem cultivation. In general, enhancing user awareness of Chinese BIM software [24,25], optimizing the software user experience, strengthening market feedback mechanisms, and increasing policy support are key pathways to promote the development of BIM software in China [32,33].

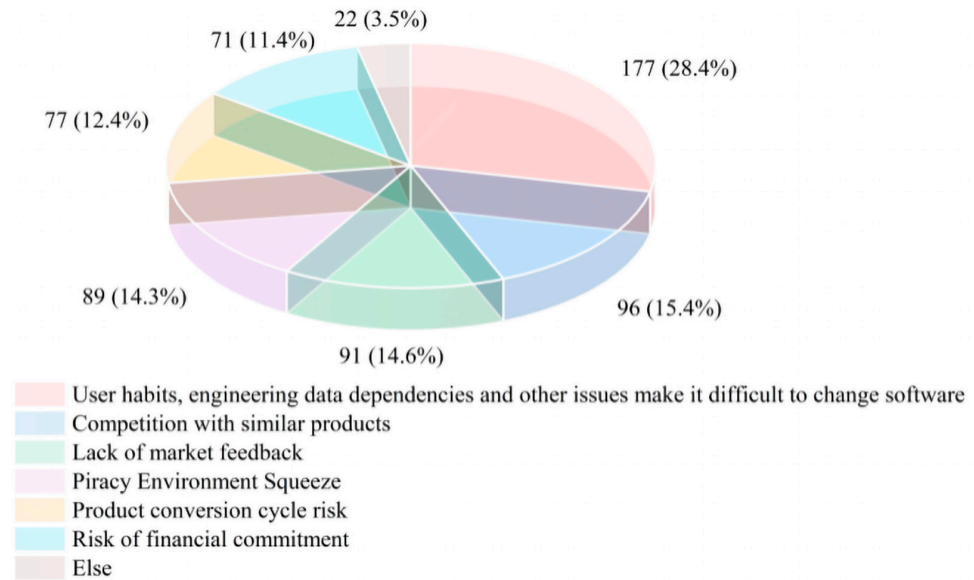


Figure 11. Factors Influencing the Application of BIM Software in China.

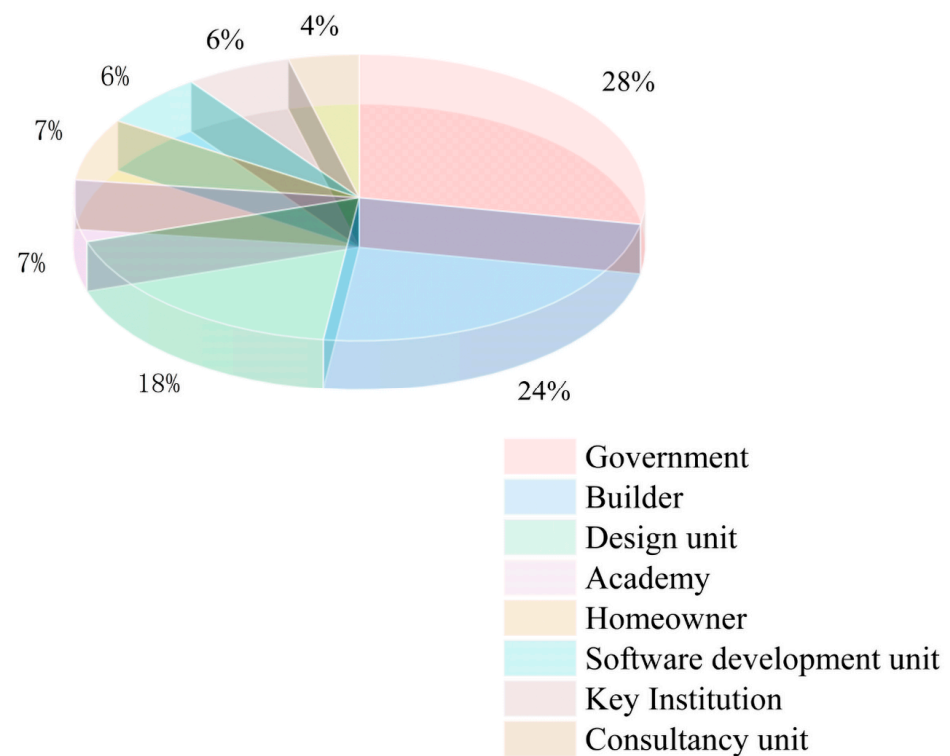


Figure 12. Composition of Units Participating in Field Research.

The research also reveals that Chinese BIM software faces multiple challenges in policy guidance, market application management, government support, ecosystem cultivation, and drawing lessons from international experiences [34]. Specific issues include the lack of policy mechanisms, incomplete BIM standard systems, lagging talent development in universities, concentration of applications in the design phase, challenges related to information security and data standardization, and an incomplete software ecosystem [35].

Furthermore, international experience indicates that the effective promotion of BIM technology requires a combination of bottom-up promotion, top-level design, and continuous development. Despite active policy initiatives by various levels of government in China since 2015 and demonstrations of China's potential in the direction of EPC [36], intelligent construction [37], and industrialized construction through BIM application competitions [35], there is still a need for enhanced support and improvement in various aspects to achieve comprehensive advancement and widespread adoption of Chinese BIM software.

4. Discussion

4.1. International Comparison of BIM Software

By studying the thesis, the macro development context was understood; through the surveys, the actual difficulties in promotion were identified, leading to the conclusions.

4.1.1. Advantages

Chinese BIM software demonstrates clear advantages in development, application, and policy support. They are more tailored to the operational habits of Chinese designers and highly compatible with Chinese engineering construction processes and standards, establishing a leading position in specific fields. Additionally, Chinese BIM software is often competitively priced, providing more economical information technology choices for small and medium-sized enterprises. Furthermore, with continuous technological advancements, Chinese BIM software is increasingly sophisticated in functionality, capable of meeting localized and diversified requirements across various stages from design to construction and maintenance. Supported by policies and market promotion, Chinese BIM software has broad development prospects and application opportunities in the Chinese market. Chinese BIM software excels in "usability" and "stability", with recognition rates of 84.45% and 69.61%, respectively. Moreover, positive evaluations have been received in aspects such as "ability to generate drawings, degree of intelligence, richness of functionalities, data security, pricing, and after-sales service", with percentages of 52.65%, 51.94%, 50.18%, 47%, and 45.58%, respectively, as shown in Figure 13.

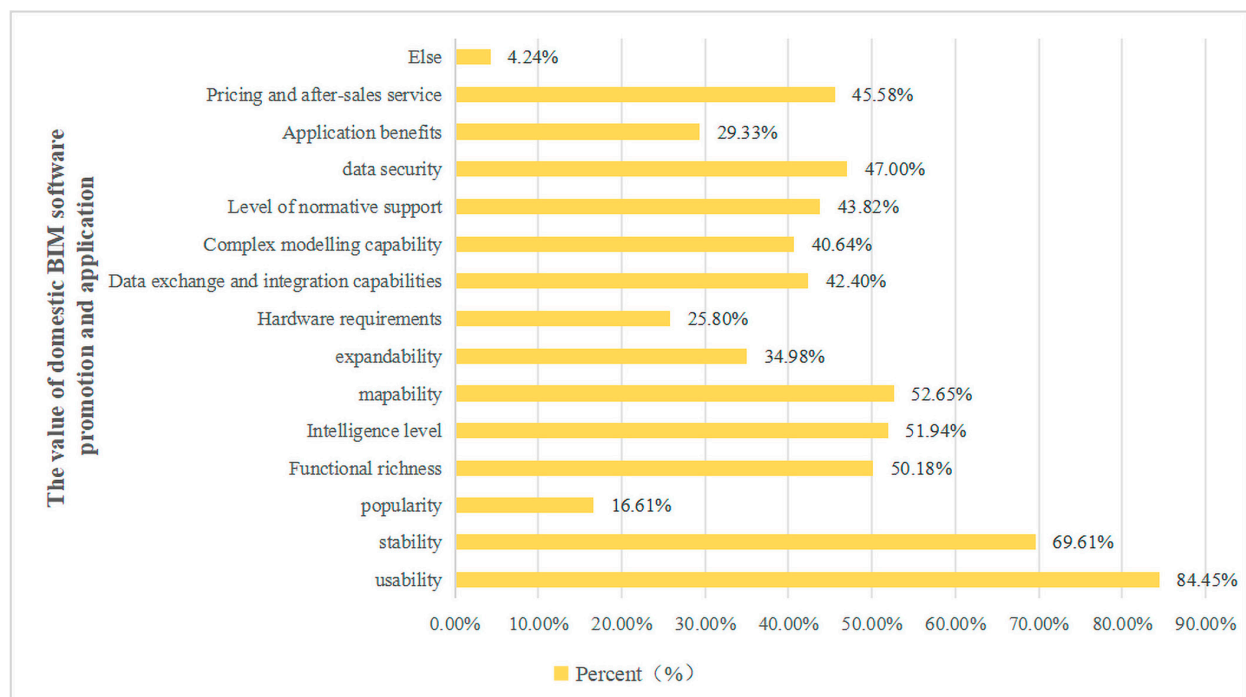


Figure 13. Characteristics of Chinese BIM Software.

4.1.2. Disadvantages

In conducting the SWOT analysis, this study distributed online questionnaires and carried out surveys in key cities to gather comprehensive data from the survey results. The strengths and weaknesses were determined based on the local promotion of the software, identifying the difficult and easy aspects of implementation, as well as the usability factors. These issues formed the basis for identifying strengths and weaknesses.

As shown in Table 3, despite the aforementioned advantages, Chinese BIM software still lags behind international advanced software in terms of functionality, performance, and outcomes, and the number of projects in actual application is relatively small.

Table 3. Analysis of the strengths and weaknesses of Chinese BIM software.

External Factors	Strength	Weakness
	Internal Factors	Ensuring Data Security; Adhering to the Habits of Chinese Designers; Compliance with Chinese Engineering Construction Standards.
Opportunities	Utilization Factors	Utilization Factors
The overall environment of the software industry is improving; Government support policies are continuously strengthening; There is a huge demand in the Chinese software market.	Provide strong supportive policies and laws for the promotion of Chinese BIM software; Promote mature Chinese BIM software; Start with conventional construction and focus on cities with sound industries; Involve multiple parties in establishing the Chinese BIM software industry alliance.	Establish a comprehensive standard system to match Chinese BIM software; Develop software based on an independent and controllable Chinese BIM data platform to enhance R&D capabilities.
Threats	Development Factors	Elimination Factors
Weak software foundation; Insufficient investment in R&D; International products taking the lead, forming an application ecosystem.	Prioritize breakthroughs in areas where some Chinese BIM software is already maturely applied; Drive the application of Chinese BIM software through the establishment of a BIM review system and an engineering big data platform.	Market uncertainty factors; Create a better market environment for Chinese BIM software to eliminate market uncertainty.

4.1.3. Analysis of Key Influencing Factors

As shown in Table 4, in order to comprehensively promote the development and application of Chinese BIM software, a series of challenges must be addressed from multiple perspectives, such as policies and regulations [38], market demand, and software development. The following table combines key issues, influencing factors [39], and solutions, aiming to provide guidance for the healthy development and market competitiveness enhancement of the Chinese BIM software industry [40].

In summary, to promote the development of BIM software in China, it requires the joint efforts of the government, enterprises, educational institutions, and industry associations. In order to promote the healthy development of Chinese BIM software and enhance its market competitiveness, we can take the following measures:

1. Formulate and implement standard specifications;
2. Establish a review platform;
3. Promote Chinese software;
4. Explore the value of data;
5. Ensure data consistency;
6. Strengthen talent cultivation;
7. Establish incentive mechanisms;
8. Promote software maturity and ecosystem construction.

Table 4. Analysis of Strengths and Weaknesses of Chinese BIM Software.

Category of Issues	Key Issues	Influencing Factors
Policies and Regulations	Policy Levers	Review Platform Government Establishment of Standards and Regulations Legal Standardization
	First Promote Software Pilot Project Pilot City	More mature and secure Chinese software Conventional construction (requires noun explanation) City with advanced construction technology and sound industry
	Talent cultivation	Establishment Competition Software Training Universities and Software Enterprises Joint Establishment
	Incentive system	Award-winning
	Value of BIM data	AI combined with intelligent construction Include BIM data costs in the project budget Uncover the value of BIM data scenarios.
Market demand	BIM data runs through the entire lifecycle of engineering projects.	Establish data standards for planning, design, review, construction, completion, and operation maintenance at each stage (requirements for data in each phase, standardized data format, consistency of BIM data circulated at each stage). During the project, compliance and standard conformity checks were carried out (suitable for integration with AI technology). Establishment of an intelligent review platform (ensuring consistency and compliance of data in all processes, and uniformity in graphical models).
	Establishing a sound BIM standard	Building Information Modeling Design Application Standards Standard for Building Information Model Operation and Maintenance Application Standard for the Application of Building Information Models in Digital Cities Completion and Delivery Standards for Building Information Modeling Building Information Model Data Interface Standard Building Information Model Review Standards Building Information Model Cost Estimating Standards Building Information Modeling Cost Standards Standard for Application of Prefabricated Building Information Model
	Promote industry collaboration.	Green Building Information Modeling Application Standard Establish Industry Alliances (Achieve Industry Consensus; Propose BIM Software Improvement Recommendations) Industry association organizes the China BIM software application competition; universities cultivate relevant talents.
	Advanced BIM software from China	Prefab, green building, engineering quantities Combining AI with Intelligent Construction
	Develop efficient BIM software in China.	Initiate Specialized Research Projects Organize training for assessing the maturity of BIM software in China and certifying software application capabilities
Software Development	Enhancing Software Collaboration	Enhance software functionality Discussing the development strategy of BIM software in China. Host a promotional event for Chinese BIM software; all project participants are invited to attend
	Promoting Software Maturity	Establishing industry alliances to promote the optimization of BIM software in China. Enhance communication between Chinese BIM software application companies and development companies. Establishing relevant research topics
	Software Ecosystem	Develop software on a Chinese software platform. Design units and the government establish a gene bank. Course opening; hosting competitions, textbooks, papers.

Through these comprehensive measures, we can not only drive the development of Chinese BIM software but also promote the digital transformation and intelligent upgrading of the construction industry, ultimately achieving continuous innovation and improvement throughout the industry.

4.2. BIM Technology Future Promotion Recommendations

As shown in Figure 14, focusing on the issues identified in software development, application, and government-related policies, it is not about competition; it is a pathway developed to better serve the construction industry in China with BIM software, rather than for international competition. There are indeed some operational steps involved. The future promotion of BIM technology needs to focus on the following five key steps.

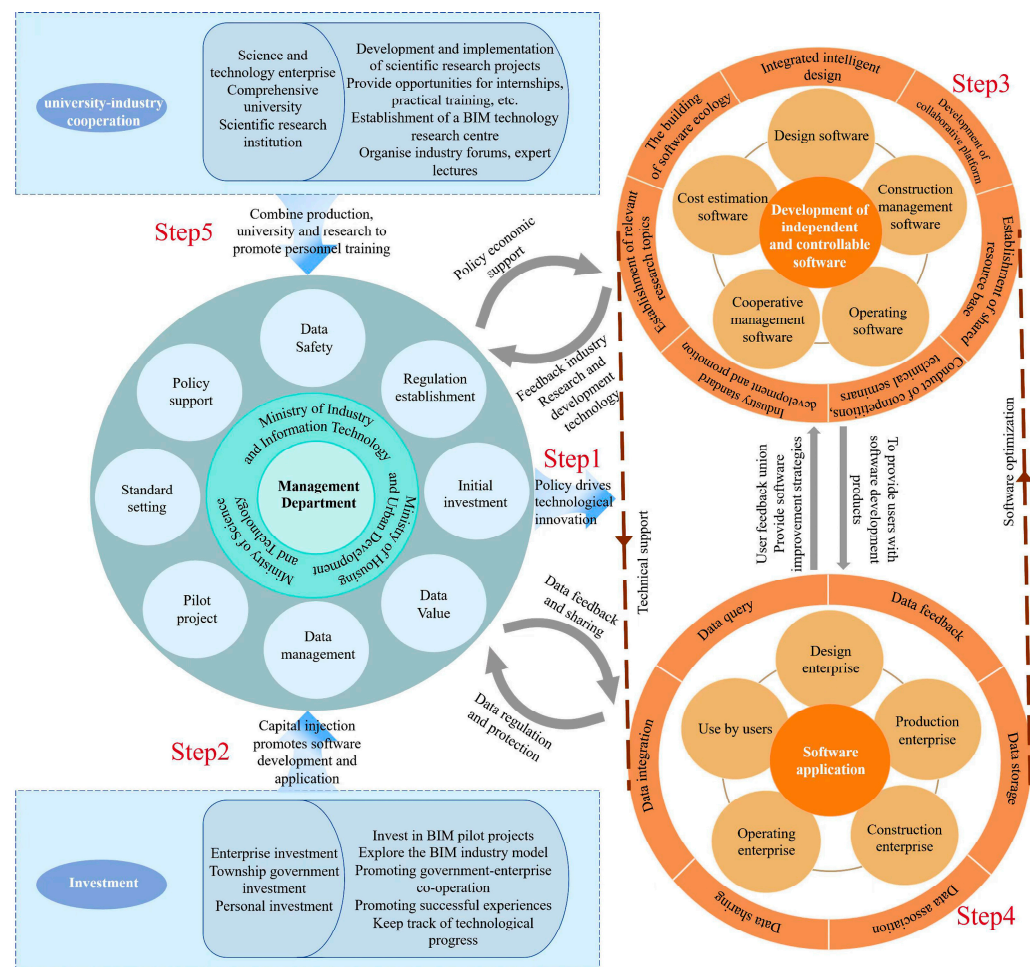


Figure 14. Outlines five key steps for promoting the application of BIM technology.

Government Responsibilities (Step 1): The government plays a crucial role in promoting the development of BIM technology. Firstly, the government needs to craft detailed policies that clearly define the role and development direction of BIM technology in the construction industry. This includes formulating specific implementation rules and operational guidelines to ensure that the application of BIM technology is governed by law and follows established protocols.

Secondly, the government should update the training system by collaborating with educational institutions to offer BIM-related courses and cultivate professionals with BIM application capabilities. Additionally, opportunities for continuing education and skill enhancement should be provided for current employees to meet the industry's demand for BIM talent.

Moreover, the government needs to establish and perfect engineering management standards, integrating BIM technology into all stages of construction, from design and construction to operation and maintenance. This would form a comprehensive BIM application standards system, which not only helps improve the quality and efficiency of construction projects but also promotes the standardized application of BIM technology within the industry.

To further stimulate market vitality, the government should set up incentive systems, as shown in Figure 15, such as financial subsidies and tax incentives, to encourage enterprises and individuals to adopt BIM technology, thereby reducing application costs and increasing willingness to use it. Additionally, the government can organize BIM technology competitions and achievement showcases to recognize enterprises and individuals who excel in BIM application, fostering a positive industry atmosphere.

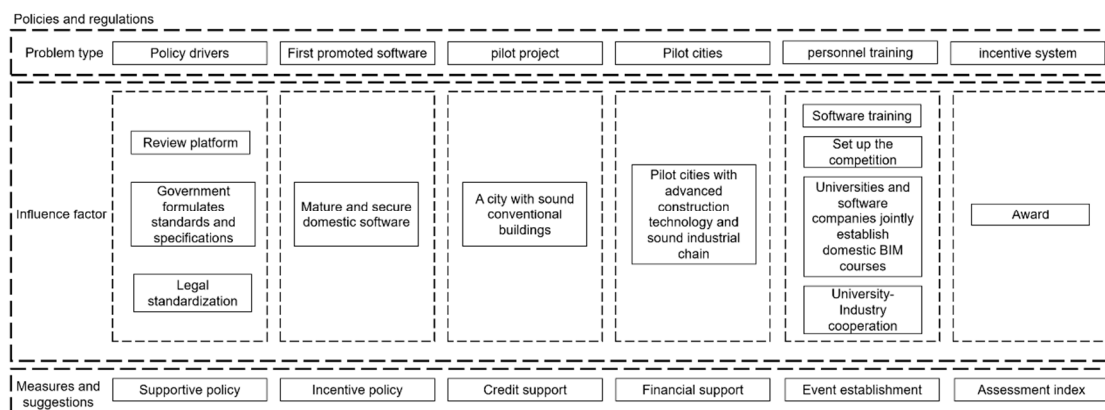


Figure 15. Policy Regulations for the Promotion and Application of BIM Technology.

Investors (Step 2): Investors play a crucial role in promoting the marketization of BIM technology. Firstly, investors should identify and invest in promising BIM technology pilot projects, which can be new construction projects, urban infrastructure construction, or the renovation and upgrading of existing buildings [43]. By investing in these pilot projects, investors can provide the necessary financial support and resource assurance for the practical application of BIM technology.

During the implementation of pilot projects, investors should closely collaborate with project teams to explore the best practices and application models of BIM technology. This includes developing detailed project plans, selecting appropriate BIM software and tools, establishing efficient working processes, and formulating risk management strategies. Through these explorations and practices, a replicable and scalable industrial model can be established, laying a foundation for the extensive application of BIM technology. Once a pilot project succeeds, investors should actively summarize experiences [45], refine outcomes, and widely promote them to other projects. This can be achieved through organizing industry seminars, publishing case studies, conducting training and workshops, etc. Through these promotional activities, awareness and acceptance of BIM technology within the industry can be enhanced, attracting more companies and professionals to engage in the application of BIM technology.

Moreover, investors should pay attention to the latest development trends and innovative achievements of BIM technology, continuously track technological progress, and constantly optimize and upgrade the application models of pilot projects. Additionally, investors can collaborate with governments, industry associations, research institutions, etc., to jointly promote policy support, standard formulation, and market promotion of BIM technology, forming a healthy industrial ecosystem.

Finally, investors should realize the long-term and complex nature of the marketization process of BIM technology, maintain patience and foresight, continuously invest resources and efforts, and support the in-depth development and extensive application of BIM tech-

nology [46]. By investing in pilot projects, exploring industrial models, widely promoting successful experiences, and continuously tracking technological progress, investors can accelerate the marketization process of BIM technology, making significant contributions to the digital transformation and innovative development of the construction industry.

Application of Corporate Responsibilities (Step 3): Enterprises play a critical role in promoting the development of BIM technology and market growth. Firstly, companies need to fully recognize the value of BIM data and regard it as a core part of their competitive advantage. By deeply exploring BIM data, enterprises can optimize design processes, improve construction efficiency, reduce operational costs, and achieve better project management.

To better manage and utilize BIM data, companies should establish a unified BIM review platform. This platform can support automated checks to ensure model accuracy and compliance, as well as provide manual review capabilities, allowing professional teams to conduct in-depth analysis and discussion of BIM models. Such a review platform helps improve design quality, reduce errors, and rework, thereby increasing the success rate of the entire project.

At the same time, companies need to continuously update their training systems to ensure employees are proficient in the latest developments in BIM technology. This includes offering regular training courses, workshops, and seminars, as well as encouraging employees to participate in external professional training and certification. Through continuous learning and skill enhancement, employees can better adapt to the development of BIM technology, creating greater value for the company. Moreover, enterprises should strengthen collaboration, sharing resources and experiences to jointly promote the application and innovation of BIM technology [45]. By establishing industry alliances or cooperative networks, companies can learn from each other, collectively solve challenges encountered in BIM applications, and drive technological progress across the industry.

Finally, companies should actively participate in the construction of a healthy market development mechanism, as shown in Figure 16. This can be achieved by formulating reasonable pricing strategies, providing high-quality customer service, and establishing a strong brand image to attract more customers to adopt BIM technology [45]. Additionally, companies should actively respond to government policy guidance, working with governments, industry associations, and other stakeholders to create a healthy and orderly BIM market environment.

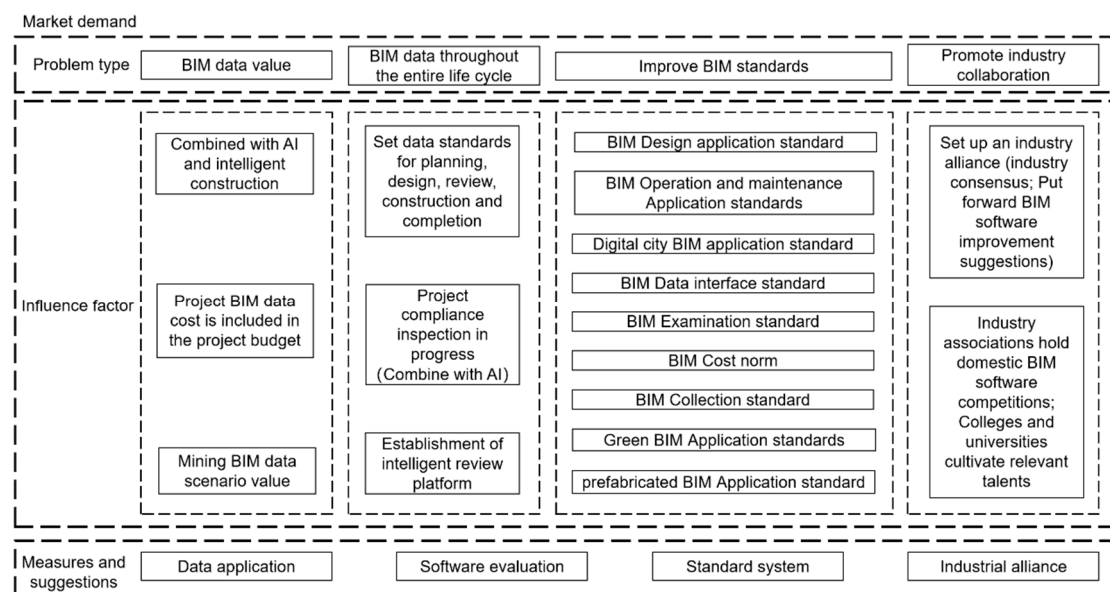


Figure 16. Market Demand for the Promotion and Application of BIM Technology.

Software Developer Responsibilities (Step 4): Software developers play a crucial role in advancing BIM technology. Firstly, developers need to deeply understand the actual

needs of the Chinese construction industry to create BIM software tailored to the national context. This involves not only meeting Chinese building regulations and standards but also considering Chinese users' operational habits and scenarios. By developing localized BIM software, it can better meet the demands of the Chinese market, enhancing software usability and user satisfaction.

Secondly, software developers should focus on integrating intelligent design features, such as artificial intelligence and machine learning, to enhance design efficiency and quality. Intelligent design can assist designers in rapidly generating and optimizing design solutions and even predicting the feasibility and potential issues of design schemes. This advancement will significantly drive the digitalization of the construction industry, elevating the industry's design standards [43]. To foster collaboration with application enterprises, software developers can establish an open collaboration platform, inviting companies to participate in software development and improvement processes. Through close collaboration with enterprises, developers can gain a better understanding of their real needs, promptly respond to market changes, and continuously enhance software functionality [45]. Additionally, software developers should establish a shared resource repository, gathering and organizing design resources, case studies, and standards within the industry [46]. This will furnish designers and companies with abundant design materials and references, boosting design efficiency and promoting knowledge sharing and technological exchanges within the industry.

To ignite industry innovation, software developers can organize relevant design competitions, technical seminars, and other activities, encouraging designers and companies to explore new applications and scenarios of BIM technology. Through competitions and seminars, innovative talents in the industry can be discovered and nurtured, propelling continuous innovation and the development of BIM technology.

Lastly, software developers should actively participate in setting and promoting industry standards, as shown in Figure 17, collaborating with multiple parties such as the government, industry associations, research institutions, etc., to collectively drive the standardized application of BIM technology in China [45]. By establishing unified technical standards and application guidelines, the widespread adoption and promotion of BIM technology within the industry can be facilitated, enhancing the overall technical competence and competitiveness of the industry.

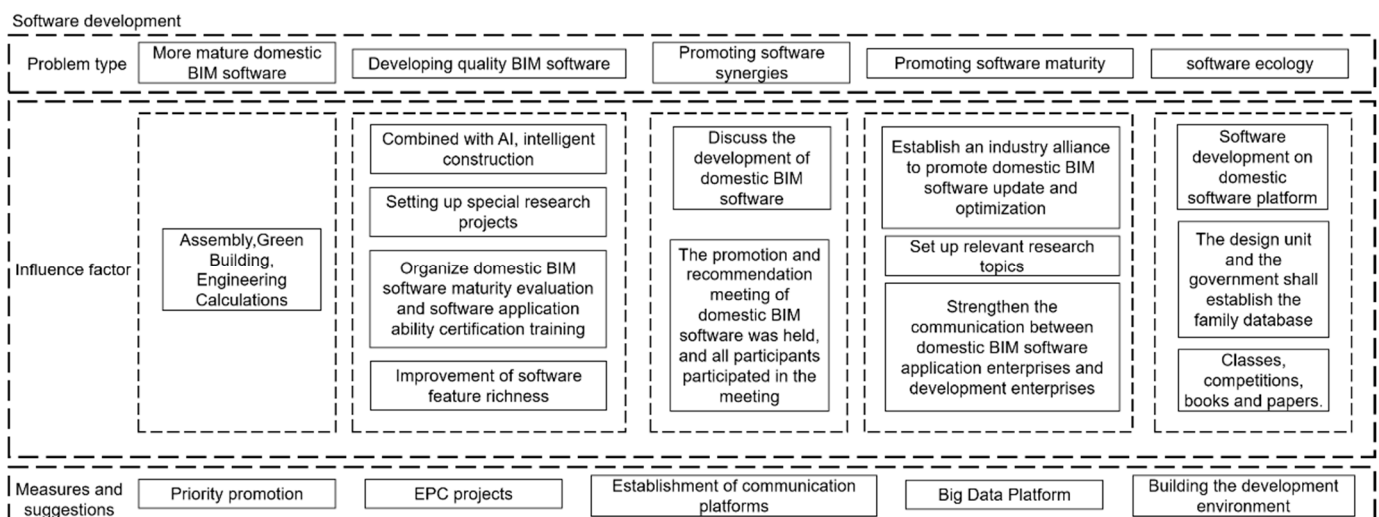


Figure 17. Software Development for Promoting the Application of BIM Technology.

Collaboration between schools and businesses (Step 5): Through school-enterprise cooperation, both parties can jointly develop and implement research projects, which can not only solve technical challenges encountered in actual engineering projects but also promote theoretical innovation and practical application of BIM technology. Universities

can provide the depth and breadth of theoretical research, while companies can offer practical application scenarios and industry experience. The close collaboration between both parties helps nurture talent who understands theory and possesses practical skills.

Furthermore, school-enterprise cooperation can allow students to learn and apply BIM technology in a real work environment through internships, practical training, workshops, project collaborations, etc. This integrated collaboration mechanism of production, study, and research not only provides valuable practical experience for students but also supplies high-quality talent for companies, achieving mutual benefits. Additionally, universities and companies can establish BIM technology research centers or laboratories together, concentrating resources on the research and innovation of BIM technology. These research centers or laboratories can serve as incubators for the development of BIM technology, continuously producing new research results and technological breakthroughs, driving the in-depth development of BIM technology. To further promote collaboration between production, study, and research, both parties can jointly organize industry forums, technical seminars, design competitions, etc., inviting industry experts, scholars, designers, and engineers to participate, share the latest developments and application cases of BIM technology, and spark innovation within the industry.

Although it may be challenging, it is necessary to implement these steps in sequence, as each step relies on the success of the previous step. Therefore, a comprehensive implementation plan is needed to ensure coordination and connection between each step. In addition, this path requires joint efforts from the entire industry, as this mechanism is a systematic project that cannot be completed by one party alone. The biggest challenge facing the implementation framework is the common goal of industrial collaboration, the rational allocation of production materials, and the formation of industrial value chains.

By implementing the above steps, localized BIM technology can be promoted in the construction industry in China, promoting the digital transformation and innovative development of the Chinese construction industry. Meanwhile, the advancements in BIM technology, as a result, also contribute to promoting the global application of BIM.

5. Conclusions

This research conducted a thorough analysis of the interactions among the three main stakeholders—the government, software users, and software developers—in the process of promoting and applying BIM software in China. It comprehensively analyzed the current situation, challenges, and future development direction. Through systematic literature review and field research, a comprehensive analysis of the current situation, challenges, and future development directions was conducted, and it was proposed to establish a benign market mechanism to promote the promotion of BIM in the AEC industry. The conclusions are as follows:

This study provides an in-depth analysis of the interaction among the three primary stakeholders—government, software users, and software developers—in the promotion and application of BIM software in China. Through a systematic literature review and field research, the current situation, challenges, and future development directions are comprehensively analyzed. The study proposes the establishment of a healthy market mechanism to promote the adoption of BIM in the AEC industry. The conclusions are as follows:

1. In the implementation planning of promoting and applying BIM software in China, the government, software users, and software developers should leverage their respective strengths and complement resources and expertise to create a synergistic effect, collectively advancing the development and popularization of BIM software in China.
2. By adopting a strategy of piloting projects, gradually expanding promotion, and eventually achieving comprehensive popularization, the application of BIM technology can steadily progress.

3. The government should intensify policy incentives, improve regulations, and enhance promotion to foster the development and application of BIM software in China.
4. Software users should effectively utilize management and incentive measures, harnessing the role of owners and feedback on requirements or issues, to promote the practical application of BIM software in real projects in China.
5. Software developers need to continuously improve software with the support of the government and users, assist homeowners in business expansion and problem-solving proactively, provide higher-quality technical services to meet market demands, and enhance the competitiveness of BIM software in China.
6. The adoption and promotion of BIM technology in China face bottlenecks, requiring more theoretical research and practical exploration. Attention should be paid to international research trends and strengthening international cooperation.
7. Measures such as piloting projects, education and training, and industry-academia collaboration, among others, can cultivate talents in BIM technology to promote the widespread application and healthy development of BIM software in China.

Author Contributions: Conceptualization, Y.W. and L.J.; methodology, Y.W. and X.Z.; software, B.Z.; validation, Y.W., Y.N., B.Z. and L.J.; formal analysis, Y.W., L.J. and B.Z.; investigation, Y.W.; resources, L.J.; data curation, Y.W.; writing—original draft preparation, Y.W. and B.Z.; writing—review and editing, Y.W.; visualization, X.Z.; supervision, X.Z.; project administration, L.J.; funding acquisition, Y.W. All authors have read and agreed to the published version of the manuscript.

Funding: This work is supported by National Key Research and Development Program of the 14th Five-Year Plan Building Information Modeling (BIM) Platform Software Supporting Nonlinear Geometric Feature Modeling (2022YFC3802100); Internal Service Platform for Digital Technology from China Academy of Building Research (Grant number 20220122330730012).

Conflicts of Interest: The authors declare no conflicts of interest.

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