Application of Landscape Engineering based on BIM Visualization Technology

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Abstract The rapid advancement of building information modeling (BIM) technology has garnered significant interest regarding its application within the domain of landscape engineering. BIM technology, as a construction and management tool that integrates digitization and visualization, has demonstrated considerable advantages in enhancing project quality, reducing costs, and improving collaborative efficiency. This study aims to systematically investigate the application and developmental trends of BIM visualization technology within the field of landscape engineering. Through an analysis of technological advancements and industry dynamics over the past decade, it has been observed that BIM visualization technology is intricately linked with green building practices, sustainable construction methods, and the development of smart cities within the context of landscape engineering projects. The technology also possesses significant potential for application in the planning and design of landscape engineering, construction management, and project maintenance. The convenience of visualization enhances the expressive capacity of the design scheme, improves communication efficiency between the involved parties, and mitigates the costs and time inefficiencies associated with design modifications. By drawing on the successful experiences of other industries and integrating them with the unique characteristics of landscape engineering, BIM visualization technology is poised to assume a more significant role within this field. This integration is expected to advance the entire industry towards greater intelligence and informatization, while simultaneously enhancing the efficiency and quality of design, construction, and maintenance processes.

Keywords BIM, Visualization technology, Landscape engineering, Visualization application

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The swift advancement of building information modeling (BIM) technology has garnered significant interest and application within the domain of landscape engineering. BIM, as a digital and visual construction and management tool, has the potential to enhance project quality and reduce costs. Furthermore, it significantly improves the efficiency of collaboration among all stakeholders involved in the project. The progress of landscape engineering in the domains of visualization, construction, and management is relatively less advanced than that of the construction industry. However, as a critical component of urban greening and environmental enhancement, the intricate nature of landscape engineering design and construction necessitates the integration of advanced technology. The visualization application that employs BIM technology provides enhanced accuracy, efficiency, and intuitiveness in its solutions, thereby creating new opportunities for the advancement of landscape engineering.

1 Overview of BIM development

A comprehensive search of the CNKI database for studies pertaining to visualization technology and landscape engineering over the past decade yielded a total of 4,408 articles (Fig.1). Subsequent analysis, including combing and word frequency assessment utilizing Citespace, revealed that the advancement of BIM tools is associated with various domains such as technology management, case comparison, multidimensional assessment, project management, dynamic identification, graphical information processing, digital twinning, or precise inspection and proofreading. The association of visualization technology with various domains such as virtual reality interaction, visual analysis, information technology analysis, collaborative design, construction technology, and big data in the field of design and construction has been recognized since 2014. This indicates that scholars have increasingly acknowledged the significant relationship between visualization technology and landscape engineering construction since that time. The advancement of visualization technology in landscape engineering is intricately linked to concepts such as green building, sustainable construction practices, smart city initiatives, and the quality of green construction.

This study undertakes a systematic investigation into the application of BIM visualization technology within the field of landscape engineering, and examines the advantages and potential applications of BIM technology in various phases, including planning and design, construction, and project management. By analyzing specific methodologies for the implementation of BIM in landscape engineering, as well as identifying existing challenges, this research aims to provide valuable insights for the digital construction of future landscape engineering projects.

In light of the increasing emphasis on sustainable development, the transition to a green and low-carbon economy has emerged as a pivotal trend in national socio-economic advancement. Within the realm of landscape engineering, the implementation of BIM technology serves not only to actualize the principles of green construction but also to optimize the management of the construction process. This optimization actively mitigates adverse effects on the ecological environment, thereby contributing to the preservation and enhancement of the ecological balance within landscape engineering[1]. In the development of an intelligent landscape engineering management system, BIM technology, in conjunction with geographic information systems (GIS), the internet of things (IoT), big data analytics, and cloud computing, facilitates three-dimensional (3D) visualization management of landscape engineering, rapid facility positioning, real-time information updates, construction quality supervision, safety protection, and cost accounting, thereby establishing a highly efficient, intelligent, and collaborative comprehensive

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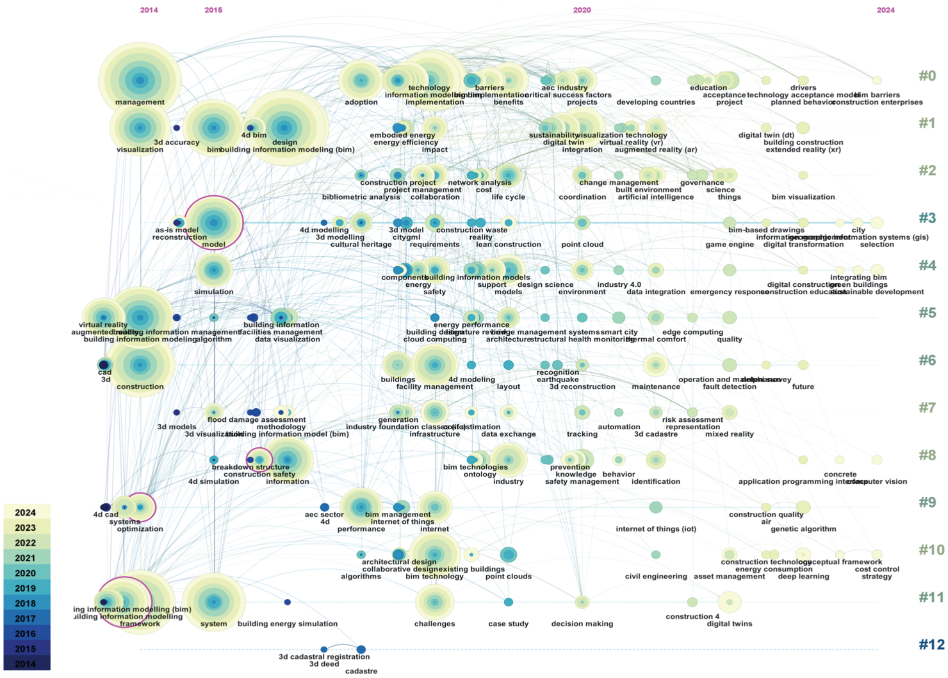

Note: #0. Cross-impact matrix multiplication applied to classification; #1. BIM facilities; #2. Comparative case study; #3. Traffic analysis; #4. Multi-dimensional simulation; #5. CAD data; #6. Design-build; #7. Structural assessment; #8. Reuse; #9. Standards; #10. Engineering management; #11. Categorisation; #12. BIM.

Fig.1 Correlation of Citespace word frequency

management system[2]. BIM technology enhances the digitalization, intelligence, and informatization of landscape management, design, and construction processes. By optimizing design solutions, visualizing active management, modeling structures, and addressing challenges, BIM technology improves the efficiency of resource integration and the quality of construction, and contributes to profitability and effective risk management[3]. The integration of BIM technology with IoT technology facilitates comprehensive data management, automated information collection, and intelligent analysis. This synergy enhances the material control process, increases the efficiency and accuracy of project management, and enables the development of an intelligent scientific model for the operation and maintenance of landscape projects[4]. BIM technology enhances communication efficiency among all stakeholders involved in a project by providing a unified 3D modeling platform. It mitigates communication barriers arising from variations in professional expertise and facilitates collaborative management, information-driven construction, and the swift measurement and control of materials and construction processes through the BIM management platform, thereby enabling a refined and highly efficient management of progress, quality, safety, and cost[5-6]. The development of smart cities is intricately linked to BIM technology, which offers a holistic approach to both internal information management and spatial information management through its integration with GIS technology. This synergy facilitates efficient management throughout the entire life cycle of urban projects, encompassing 3D modeling and analysis, information integration, enhancement of construction efficiency and quality, as well as environmental and safety management. Furthermore, it promotes collaborative work and possesses significant potential for widespread application, thereby providing robust technical support and solutions for the advancement of smart cities[7].

BIM technology enhances communication and construction planning by employing advanced technical collision detection within the management of landscape engineering projects. Furthermore, it improves construction quality through precise material calculation and management. Consequently, BIM serves as a critical technical tool for achieving high-quality living environment construction during the urbanization process[8]. The implementation of novel technologies and materials in municipal landscape engineering not only enhances resource utilization efficiency and environmental quality, but also propels the advancement of associated industries. These include the development of hydraulic spraying technology to optimize the grass-planting process, BIM technology to enhance design and planning, and the integration of green environmental protection concepts. Furthermore, the utilization of innovative materials, such as permeable materials, universal supporters and imitation wood materials, collectively promotes efficient, environmentally friendly and sustainable development of landscape engineering[9]. The integration of internet+, big data, the establishment of standardized templates and professional models, the application of simulation technologies ranging from three-dimensional (3D) to five-dimensional (5D), and their incorporation into management platforms facilitate collaborative development within the construction sector. This approach also enables the integrated and efficient management of the garden industry supply chain, representing a significant advantage in the field[10]. BIM technology possesses the capacity to significantly improve efficiency in construction management, optimize resource allocation, and enhance project quality in municipal landscaping projects. The potential application of BIM technology in the construction of smart cities is anticipated to significantly improve construction management efficiency, optimize resource allocation, and enhance the quality of municipal landscaping projects. This improvement is expected to occur through comprehensive life cycle management, enhanced information circulation and interaction, the implementation of scientific design principles, the refinement of construction management practices, quality and schedule control, cost management, and technological integration. Consequently, it is poised to become a pivotal technical force driving advancements in the landscape industry and the development of smart cities[11].

The accelerating process of global urbanization has led to a deceleration in large-scale development and construction within the landscape engineering sector in recent years. However, the demand for upgrading and transformation continues to increase, necessitating that projects achieve higher standards in all facets of design, construction, and management. The implementation of BIM technology has the potential to significantly improve the information management capabilities within landscape engineering. Particularly when supported by visualization technology, BIM facilitates a more intuitive resolution of complex challenges encountered during the landscape design and construction processes. Consequently, this integration enhances both construction efficiency and quality. Concurrently, the swift advancement of big data, IoT, and other emerging technologies will inevitably steer BIM technology towards greater intelligence and integration, thereby further enhancing the informational construction of landscape engineering.

The process of digitalization in landscape design in China commenced in the early 1970s with the introduction of computer-aided design (CAD) technology. This advancement significantly enhanced the efficiency of drawing and improved the accuracy of design outcomes. As we progress into the 21st century, advancements in technology have led to the increasing popularity of rendering tools such as Lumion and Mars in the field of garden design. These tools offer enhanced capabilities for producing vivid and realistic renderings and animations, thereby augmenting the expressiveness of design proposals. However, these tools primarily focus on the visual elements of presentation and exhibit limited capabilities regarding information integration and construction management.

The implementation of BIM technology in landscape architecture encompasses various technical components, including the analysis of existing conditions, the creation of construction drawings, the development of 3D models, and the assessment of performance outcomes. This approach integrates knowledge from multiple disciplines, such as geography, geology, soil science, the humanities, and biological sciences, thereby enhancing the comprehensiveness and scientific rigor of landscape architecture design[12]. In 2012, Sun Peng et al.[13] conducted a comprehensive analysis of the application of BIM technology both domestically and internationally. They concluded that BIM technology plays a crucial role in the field of landscape architecture and garden planning and design, drawing insights from its successful implementation within the construction industry. The utilization of BIM technology in landscape architecture design is crucial for enhancing design efficiency and for the prediction and resolution of potential issues. This application can substantially minimize design errors attributable to human factors and facilitate comprehensive oversight and optimization of landscape design outcomes, thereby ensuring the successful execution of projects[14]. The research perspective presented in Chen Qianru's paper centered on the development of a dynamic data fusion framework utilizing BIM to conduct an in-depth analysis of carbon emissions and energy consumption data. This framework aimed to elucidate the relationship between the assessment indicators of low carbon and green buildings, thereby facilitating the establishment of a comprehensive whole life cycle assessment system. Additionally, the paper proposed the creation of an integrated BIM application system for low-carbon buildings, which is intended to foster the advancement of domestically developed software and to improve the efficiency of whole life cycle carbon footprint management in the building sector[15].

2 Development trend of BIM technology visualization application

Over the past decade, numerous domestic universities and research institutions have increasingly focused on the application of BIM in landscape engineering. Notable institutions such as Tsinghua University and Tongji University have conducted research on the implementation of BIM technology within this field, yielding significant results. BIM technology, following years of development, is increasingly being implemented across all facets of project management. This is achieved through the creation of multi-dimensional information models, which facilitate comprehensive information integration and collaborative management throughout the entire process, from design to construction. Nevertheless, owing to the intricate nature and varied aspects of landscape engineering, the implementation of BIM technology within this field necessitates further advancement and enhancement.

In the domain of contemporary garden engineering and landscape design, the utilization of BIM technology is increasingly prevalent. This approach demonstrates considerable advantages in enhancing design precision, construction efficiency, and project management. Through a series of case studies, this analysis elucidates the role of BIM technology in various projects and its impact on fostering technological innovation within the landscape industry.

Based on the current research findings, Dong Zefeng[16] utilized the Shanghai Disney Phase 1.5 project as a case study to illustrate the application of BIM technology throughout the entire life cycle of landscape engineering. The discussion encompassed the accuracy requirements of the model, the various modeling methodologies employed, and the ways in which BIM technology can enhance both the accuracy and efficiency of design and construction processes. Li Lei et al.[17] utilized the Nanjing Qinglong Green Belt Phase II Project as a case study to illustrate the application process and impact of BIM technology in real-world projects. This approach offered several advantages, including 3D intuitive visualization, rapid and precise analysis, and dynamic updates of numerical data. These benefits significantly alter the perspectives of landscape designers in their analysis and design of terrain. Chen Kai et al.[18] conducted an analysis of the scope of application, technological implementation, and practicality of BIM technology within the landscape industry, using the "Baihuyuan" project as a case study, and summarized the application of BIM technology in various aspects, including project quality control, cost management, and collision detection. Using the Guangzhou Baiyun Airport Noise Management Project Resettlement Area Engineering Project as a case study, Huang Zhichao[19] illustrated the application and impact of BIM technology in real-world landscape garden engineering projects. Furthermore, the study examined the emerging trends in the application of BIM technology concerning landscape support development, material management, two-dimensional code management, green engineering, and modular construction. In the domain of topographic surveying and design, Xing Yu et al.[20] demonstrated a methodology for utilizing BIM technology to develop a ground model through the rapid conversion of topographic map data. Additionally, they conducted an analysis of the processing techniques associated with this model. Huang Ling[21] illustrated the practical application and effectiveness of BIM technology following secondary development in the context of landscape engineering topography design. This was exemplified through the case study of the Fengming Lake East and West Tributary Landscape Enhancement Project located in the Xicheng District of Zaozhuang City. He Qiusheng[22] utilized an urban expressway project as a case study to demonstrate the application of BIM technology in road design, including the establishment of terrain surfaces, line design, and safety evaluation methods. This approach is indicative of the integration of road design within landscaped environments. Tian Nannan[23] utilized the green belt project located within the new economic zone of a first-tier city in the southern region as a case study, and employed Autodesk Civil 3D software to perform vertical analysis and integrated BIM technology to enhance the decision-making process for designers. This approach facilitated more informed decisions regarding the design of vegetation planting, plaza and roadway configurations, building placement, site drainage, and water management systems, etc. Using the Shanghai National Convention and Exhibition Center as a case study, Wang Xinxin[24] demonstrated the potential of BIM technology to enhance design and construction management in large-scale landscape projects. The application of digital tools facilitated improvements in design quality and construction efficiency. Furthermore, BIM technology enabled the design team to collaborate on an integrated platform, thereby ensuring a precise articulation of design intent and effective oversight of the construction process. BIM technology facilitated the integration of rational thought in the planning process by enabling designers to create digital models and analyze various construction elements, including elevation, slope direction, and slope gradient of a site. Guo Fujian et al.[25] utilized the vertical design of Ruilong Country Park within the Nanjing Qinglong Green Belt Phase II Project as a case study, illustrating the fundamental processes of site modeling, analysis, and vertical design through the application of Civil 3D software. The Xuzhou Garden Expo Park project effectively integrated advanced planning and design, construction management, completion acceptance, and operation and maintenance management through the utilization of "BIM+GIS" technology[26]. This integration enhances communication efficiency and elevates management standards.

3 Application of BIM visualization technology

3.1 Application of green garden and green building design

The implementation of BIM technology in the design of green gardens and green buildings facilitates a more scientific and rational optimization of programs through the integration of information. During the design phase of a project, the BIM model enables the comprehensive design of various elements, including plant allocation, water system design, and environmental simulation, thereby achieving low-carbon environmental protection and sustainable development.

The BIM technology encompasses a wide range of applications, including the simulation of energy consumption and the planning of material optimization phases. It also involves the management of quality, cost, and scheduling during the construction phase, as well as the optimization of real-time monitoring and operational strategies during the operation and maintenance phases. These efforts aim to achieve energy efficiency and reduce carbon dioxide emissions[27]. The research conducted by Yang Yang et al.[28] substantiated the utilization of BIM digital technology across various phases, including design, construction, operation, and maintenance management. The study highlighted the enhancement of IoT elevator monitoring, the 3D printing of building components, as well as the integration of big data and artificial intelligence for energy management. Guo Wenbo et al.[29] demonstrated the substantial impact of BIM technology on enhancing construction efficiency and facilitating sustainable construction practices. They further elaborated on its significance in the context of smart construction, focusing on two key aspects: the integration of intelligent systems and the reduction of costs alongside environmental sustainability.

3.2 Applications in conflict detection in construction links

The construction complexity associated with the landscape project is considerable. Therefore, BIM visualization technology can be employed to identify conflicts and enhance the design of the construction process. The BIM model possesses the capability to simulate all facets of the construction process, thereby enabling the identification and resolution of potential issues prior to their occurrence, which ensures a seamless construction experience. For instance, the lifting operations of large equipment and the concurrent execution of various construction processes can be intuitively simulated and modified through the multi-dimensional visualization technology inherent in BIM.

The implementation of BIM visualization technology in landscape architecture encompasses various aspects such as local design, engineering, and intelligent landscape systems. This integration contributes to enhanced design precision and increased construction efficiency[30]. The simulation and emulation of landscape buildings and structures through BIM facilitates the identification and rectification of defects, optimizes the construction process and organizational design, reduces the construction cycle duration, and enhances the safety and quality of buildings. BIM technology facilitates real-time collaboration by employing centralized data management. It utilizes 3D simulation to enhance safety, 4D simulation to optimize project progress, and 5D simulation to improve cost control. Additionally, the integration of sensor data ensures quality assurance. Collectively, these features contribute to the overall efficiency and quality of landscape engineering construction[31].

3.3 Applications in changing communication patterns between parties A and B

The visualization capabilities of BIM technology significantly enhance the communicative effectiveness and expressive capacity of design proposals, thereby facilitating smoother interactions between parties A and B. During the design modification process, the BIM model enables the rapid generation of updated 2D drawings and 3D models, which substantially decreases both the costs associated with communication and the time lost due to design alterations.

BIM technology serves as both an external factor and an internal developmental requirement within the landscape architecture industry. It has the potential to effectively address design errors and coordination challenges, thereby enhancing design quality and construction efficiency[32]. The utilization of a standardized 3D digital modeling platform, along with clearly defined design steps, detailed building specifications, and comprehensive cost information, enhances the intuitiveness and comprehensibility of the construction process. Furthermore, it improves the consistency of construction data and optimizes the construction organization plan[33]. The implementation of BIM technology in the design and construction of landscape architecture engineering projects can significantly enhance communication and collaboration between the involved parties by autonomously simulating various activities to effectively convey design concepts[34-35].

4 Conclusions

This study conducts a systematic review of the application and developmental trends of BIM visualization technology within the field of landscape engineering. By examining the current state of research both domestically and internationally, as well as analyzing exemplary case studies and specific applications, the significant potential of BIM technology in landscape engineering is thoroughly elucidated.

(1) BIM technology, recognized as a digital and visual tool for construction and management, has demonstrated considerable advantages in the field of landscape engineering. BIM technology enhances the precision of design and construction processes while fostering closer collaboration among stakeholders. Additionally, it improves the efficiency of information exchange through the application of 3D visualization techniques. This technology significantly contributes to the development of green buildings, sustainable construction practices, and smart cities by optimizing construction processes, minimizing adverse effects on the ecological environment, and maintaining the ecological balance of

landscape projects.

(2) The integration of BIM with the IoT, big data, and other advanced technologies facilitates the intelligent management of landscape projects. This integration optimizes the material control process through automated data collection and intelligent analysis, thereby significantly enhancing the overall effectiveness of project management. These instances not only illustrate the extensive application of BIM technology but also highlight its comprehensive management efficacy throughout the entire project life cycle.

(3) BIM technology possesses significant potential for application in conflict detection and design optimization within the construction process. It enables the identification and resolution of potential issues prior to construction, thereby enhancing both efficiency and quality. Furthermore, BIM technology facilitates improved communication between stakeholders A and B. The visualization capabilities inherent in BIM technology markedly enhance communication effectiveness while simultaneously reducing the costs and time inefficiencies associated with design modifications.

Although the implementation of BIM technology in landscape engineering remains in its early stages, ongoing advancements in the technology and increasing acceptance within the industry suggest that BIM will attain broader application in landscape engineering. This progression is expected to facilitate the intelligent and informational advancement of the sector. The extensive utilization of BIM in planning and design, construction management, and project maintenance enhances the accuracy and efficiency of both design and construction processes. Furthermore, it optimizes the management of the entire project life cycle, thereby offering innovative solutions for the sustainable development of landscape engineering.

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