BIM Technology for Quality and Efficiency Enhancement in Existing Building Renovation Projects

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Abstract

This study investigates the problem of missing original as-built data and documentation affecting renovation projects for existing buildings, and introduces an integrated approach combining reverse engineering technology based on 3D laser scanning, point cloud data processing technology, and BIM technology to address this issue. Applied throughout the project design and construction processes, this approach enhances the feasibility of design schemes and provides effective solutions for optimizing mechanical and electrical installation as well as controlling clear height in existing buildings.

Full Text

BIM Technology for Quality and Efficiency Enhancement in Existing Building Renovation Projects

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Abstract: This paper studies the problem that, in existing buildings, the absence of original as-built data affects renovation projects. It introduces a reverse-engineering technology based on three-dimensional laser scanning, point-cloud data processing technology, and BIM technology. By combining these technologies, the above-mentioned problems are solved and the methods are applied in the project design and construction process, improving the feasibility of the design scheme and providing an effective solution for optimizing mechanical and electrical installation and controlling clear height in existing buildings.

Keywords: BIM technology; existing buildings; reverse engineering; demolition quantity takeoff; clear-height control

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1 Introduction

The *Outline for Informatization Development in the Construction Industry* issued by the Ministry of Housing and Urban-Rural Development states that, during the "12th Five-Year Plan" period, the application of new technologies in engineering—such as building information modeling (BIM) and network-based collaborative work—should be accelerated; three-dimensional design technologies based on BIM should be explored and studied; highly parameterized, visualized, and performance-based design capabilities should be improved; and technical support should be provided for integrated design and construction. During the construction stage, research and application of BIM technology should be carried out, promoting the extension of BIM technology from the design stage to the construction stage and reducing attenuation in the process of information transmission[^1]. During the "13th Five-Year Plan"period, the level of informatization in the construction industry should be comprehensively improved, efforts should be made to strengthen the integrated application capabilities of BIM, big data, intelligence, mobile communications, cloud computing, the Internet of Things, and other information technologies, and building engineering design, production, transportation, assembly, and full-life-cycle management based on BIM should be promoted, so as to advance industrialized construction[^2].

2 Project Overview

The National Tobacco Quality Supervision and Inspection Center Scientific Research and Testing Center construction project is located in the Weikemu Park of the National 863 Central Software Industry Base in the Zhengzhou High-tech Development Zone. This project is a renovation of an existing building. The construction scope is to transform the original office building and factory building into a scientific research and testing center focused on inspection and testing, as shown in Figure 1. The total floor area of the project is 21,253 m^2, of which the renovation area is 19,852 m^2, with a total investment of 295 million yuan. The existing laboratories and workplaces have seriously constrained the development of the quality inspection center. In order to meet the needs of industry development, safeguard national interests and consumer interests, further improve testing standards, and strengthen the tobacco industry' s ability to participate in international competition, the purchase and renovation of the quality inspection center' s scientific research and laboratory building are very necessary and of far-reaching significance.

The overall objective of the project is to build a first-class domestic and internationally advanced tobacco inspection and control laboratory. High standards are required for construction quality and for maintainability after completion. Through detailed design and lean management using BIM technology, the project addresses the many constraints and the high implementation difficulty faced in the renovation of existing buildings, ensuring the achievement of the project' s construction-quality objectives. Ultimately, a digital model of the scientific research and laboratory center will be completed, laying a data foundation for visualized operation and maintenance management.

Figure 1 National Tobacco Quality Inspection Construction Project

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Author profile: Wang Fenglei (1986–), male, engineer, BIM project manager. Mainly engaged in the application and implementation of BIM technology.

3 BIM Technology Application Implementation

3.1 Reverse Engineering and Point-Cloud Processing

This project is a renovation project for an existing building. Since the project was put into use in 2006, the archived original as-built documentation has been seriously missing; the available drawing materials differ greatly from the current engineering conditions. The existence of these problems brought enormous difficulty to designers in restoring accurate building data information within the prescribed time, and could not satisfy the requirements of detailed design. For this reason, reverse-engineering technology based on three-dimensional laser scanning was adopted to collect data on the on-site buildings, and BIM technology was used to restore and create a building information model.

Three-dimensional laser scanning technology is another technological revolution in the field of surveying and mapping following GPS technology. It breaks through the traditional single-point measurement method, and can rapidly scan the measured object and directly obtain high-precision three-dimensional point-cloud scanning data without the need for a reflecting prism. In this way, it can efficiently create and virtually reproduce a three-dimensional digital building information model of the real world, and can rapidly, accurately, and reliably complete tasks such as the calculation, analysis, and inspection of distances, dimensions, areas, and volumes, as well as digital documentation work, giving it unique advantages [3–4].

In the early stage of project design, reverse-engineering technology based on three-dimensional laser scanning was used to conduct laser scanning and point-cloud data acquisition for the exterior façades of the buildings in the campus, the campus itself, and surrounding roads and facilities. Scene point-cloud processing software was then used to perform position-information merging on the acquired point-cloud data. Through EdgeWise software, the point-cloud data were extracted, processed, transformed, and used to create a three-dimensional information model, which was finally imported into the Revit three-dimensional design platform to form a BIM model with accurate dimensions of the original buildings as the design basis, as shown in Figure 2. From data acquisition to model integration and processing, only 8 days were spent, greatly shortening the time required for restoration of the original data, while also providing complete on-site data materials for preliminary design and ensuring the accuracy of the data needed for preliminary design.

3.2 Quantitative Analysis of Demolition and Renovation

When carrying out civil engineering demolition and renovation inside a building, the quantitative analysis of engineering quantities is indispensable [5]. The first floor of Building No. 5 was originally designed as a commercial outlet, with a storey height of 4.5 m; the second to tenth floors were originally designed as residential units, with a storey height of 3.6 m. The original design adopted a layout of large spaces with small partitions, meeting the application needs at that time. At the present stage, structural reinforcement and renovation are being carried out for Building No. 5 as a whole. In accordance with changes in function, new requirements have also been proposed for the spatial layout of the first floor. The first-floor design currently planned includes a lobby, duty room, BAC library, BAC library materials room, BAC library, UPS power room, BAC library preprocessing room, information-center machine room, control room, spare-parts warehouse, toilet, stairwell, and elevator hall.

Compared with the original design, many functional rooms have been added. Except for the elevator shaft, stairwell, and plumbing/electrical shaft, the internal partition walls of the original building are almost entirely demolished. The quantities for removing old wall areas and constructing new wall areas are relatively large. In view of the project' s large renovation scope, heavy workload in demolition-and-renovation quantity statistics, and poor accuracy, the demolition-and-renovation positions of the original building model and the renovated model were checked and the demolition/renovation types were designated. A secondarily developed data-statistics module was then used to realize rapid statistics and calculation of demolition-and-renovation quantities, improving data accuracy and achieving the purpose of refined management of engineering budgets, as shown in Figure 3.

At the same time, safety management during the renovation process must constantly raise the alarm. By using the BIM model to conduct visual project safety management, such issues as reserved openings at hazardous locations that must not be approached, temporary electrical facilities that must not be operated carelessly, and zones for hazardous sources or material stacking that must not be blocked can be clearly identified. Before construction, this can vividly serve as a warning and educational tool for all participating personnel, thereby avoiding safety accidents.

Figure 2 Three-dimensional laser scanning and point-cloud processing

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Figure 3. Quantitative analysis of demolition and renovation

Figure 3: Figure 3. Quantitative analysis of demolition and renovation

Figure 3 Quantitative Analysis of Demolition and Renovation

3.3 Deepening of MEP Installation and Clear-Height Control

Using BIM technology in combination with construction techniques, the construction drawings were deepened in three dimensions. Comprehensive pipeline optimization was carried out from two aspects—the conventional functional areas and the laboratory process areas—so as to improve the design quality of the construction drawings [6-7].

For conventional functional areas such as offices, corridors, and station rooms, integrated pipeline deepening design was carried out for each area in accordance with the owner' s clear-height requirements and decoration effects, and feasible optimization results were fed back in a timely manner. Based on the finalized BIM integrated pipeline design, detailed design of supports and hangers was performed, with full consideration given in advance to the effective use of installation space during construction. Accurate quantity statistics obtained through the BIM model can be used in the early design stage for cost estimation, for exploring different designs within the owner' s budget range, or for comparing the construction costs of different design schemes. The use of BIM integrated pipeline design drawings enables BIM drawings and models to be viewed on site at any time during the later construction process, making it easier to guide construction, promptly solve site construction problems, and ensure the smooth progress of project construction.

For the laboratory process areas, in addition to public MEP pipelines, it was also necessary to consider the spatial arrangement of a large number of process pipelines, the environmental factors caused by acidic gases in the rooms that corrode the pipelines of various disciplines, and the operating-space requirements for inspection and maintenance of concealed works above the suspended ceiling in the later stage by the owner. Taking all these factors into account, the deepening and optimization design of all pipelines was carried out, satisfying the laboratory use requirements in the renovation and achieving the goal of building high-standard laboratories.

The focus of MEP installation control in this project was to carry out refined design of MEP pipelines within the limited space under the preconditions of limited floor height of the existing structural story, reinforcement of beams and columns, and the addition of laboratory process pipelines, so as to meet the laboratory control requirements for constant temperature and humidity, cleanliness, and high clean-room performance.

Based on clear-height analysis data, the MEP design made full use of the structural beam space and the height difference within the ceiling. Measures such as adjustment of pipeline routes, optimization of pipeline sizes, advance reservation of openings in the steel structure, and special treatment of conflict locations were adopted. A self-developed BIM MEP specialty deepening-design tool was used to optimize the layout of MEP pipelines, and the reserved maintenance space, support-and-hanger installation form, and root-fixing method were deepened. Finally, through BIM clash detection and adjustment optimization, the clear-height requirements of each functional area were effectively guaranteed, as shown in Figure 4.

After completion of the MEP pipeline deepening-design model, rapid arrangement, coding, and detailed drawing design were carried out for pipeline supports and hangers; reserved openings for the installation of newly added pipelines were automatically generated and quickly annotated by category; the quantities of MEP pipeline works and the steel consumption of supports and hangers were accurately calculated; and integrated pipeline design drawings in multiple forms –including plans, sections, axonometric drawings, support-and-hanger layout drawings, and support-and-hanger detail drawings–were adopted to guide on-site installation, as shown in Figure 5.

Figure 4. Clear-height analysis and control

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Figure 4 Clear-Height Analysis and Control

Figure 5. BIM detailed design for MEP installation

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Figure 5. BIM detailed design for MEP installation

4 Conclusion

By integrating reverse engineering based on 3D laser scanning, point-cloud data processing technology, and BIM technology, this project solved the common problem of missing data in existing building renovation projects and improved the feasibility of the design scheme. Moreover, the inherent advantages of BIM technology in visualization and spatial coordination provided an effective means for optimizing MEP installation and controlling clear height in existing buildings. As renovation projects continue to increase in the future, technologies such as BIM, 3D laser scanning, "Internet +" mobile applications, and others will be applied more widely, and will play a greater role in improving project management and operation-and-maintenance management.

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BIM Technology Helps to Improve the Quality and Efficiency of Existing Building Renovation Projects

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Abstract: This paper studies the problems existed in the existing buildings transformation due to the influences of lacking original completion data, and introduces the method of combining reverse engineering technology, point cloud data processing technology and BIM technology together based on 3D laser scanning, to solve the problems mentioned above. The application of the method in project design and construction process has improved the feasibility of the design, as well as provided an effective solution to optimize and control the height of electromechanical installation of existing buildings.

Key Words: BIM Technology; Existing Buildings; Reverse Engineering; Quantification of Demolition; Net Height Control

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Figures

Source: ChinaXiv. Machine translation. Verify with the original.

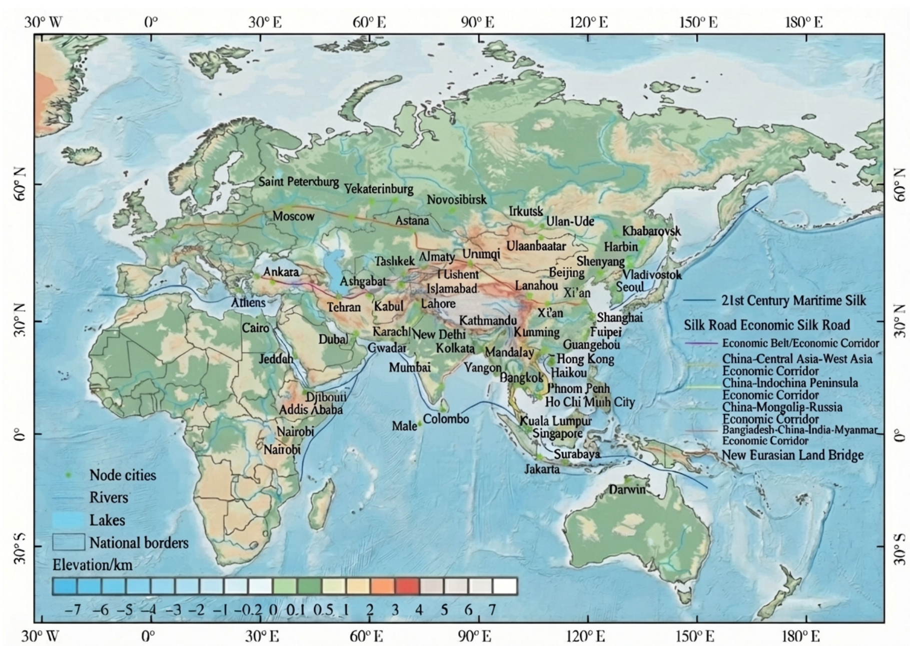

Figure 6: Figure 1

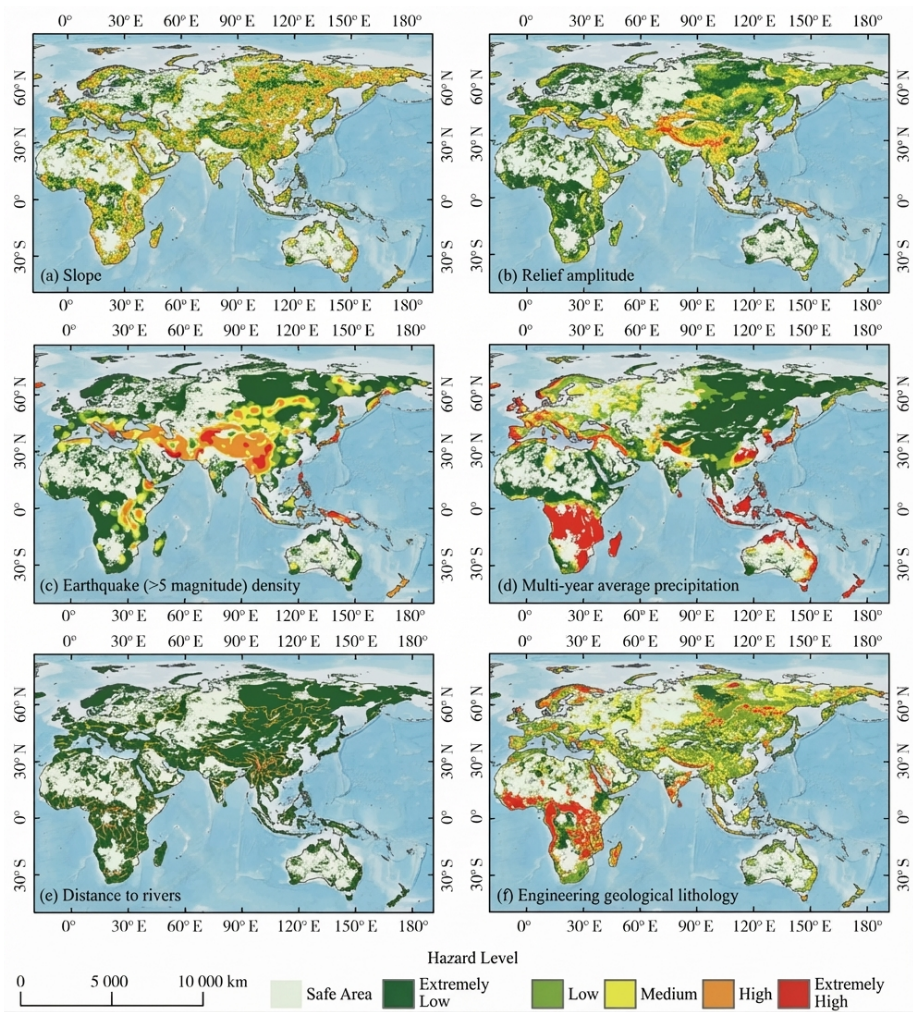

Figure 7: Figure 2

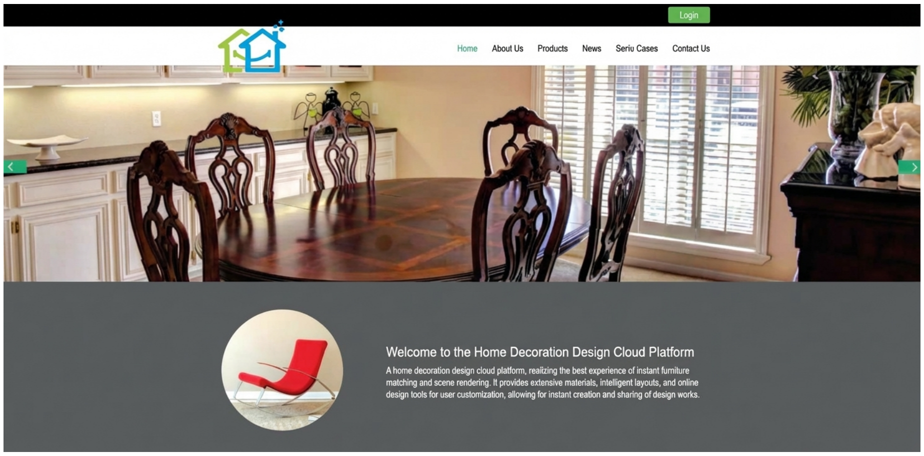

Figure 8: Figure 3

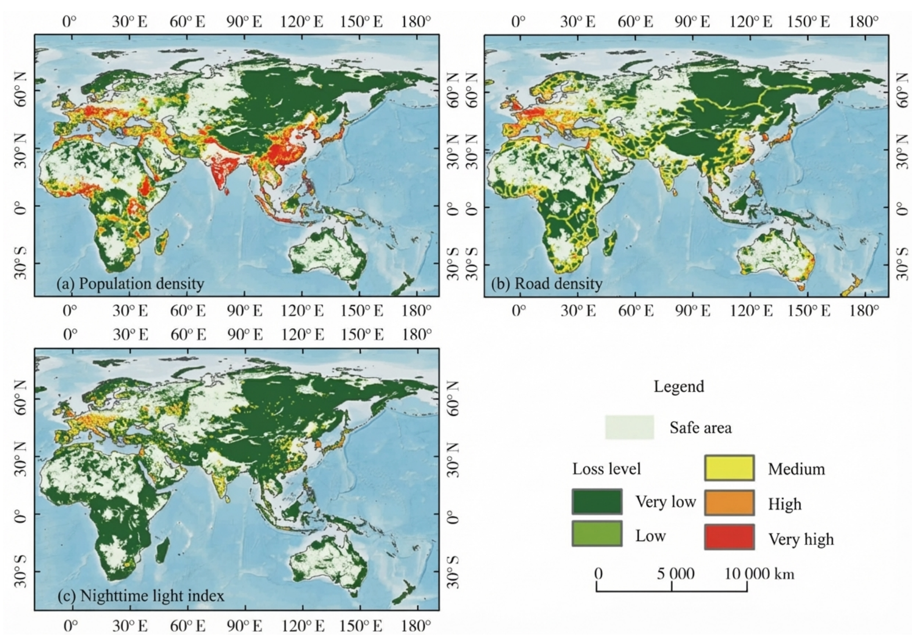

Figure 9: Figure 4

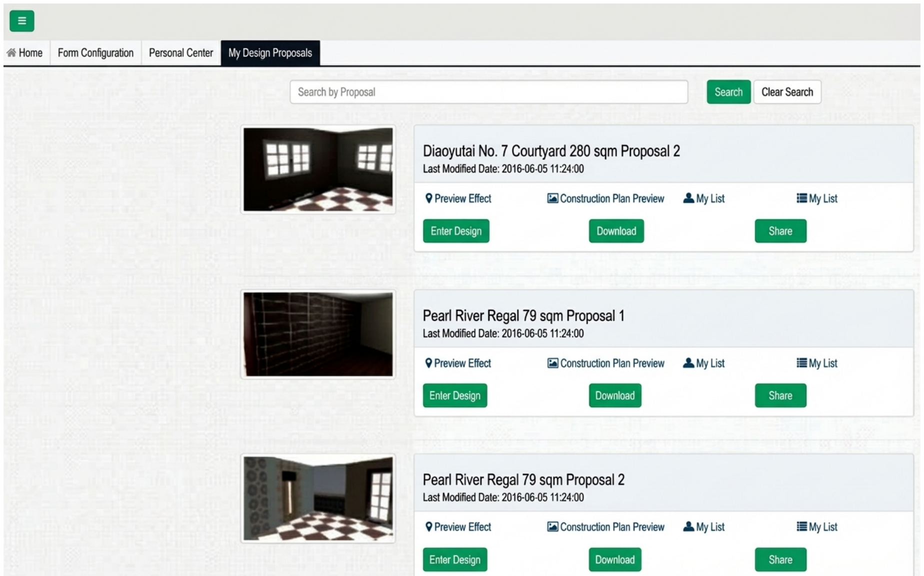

Figure 10: Figure 5

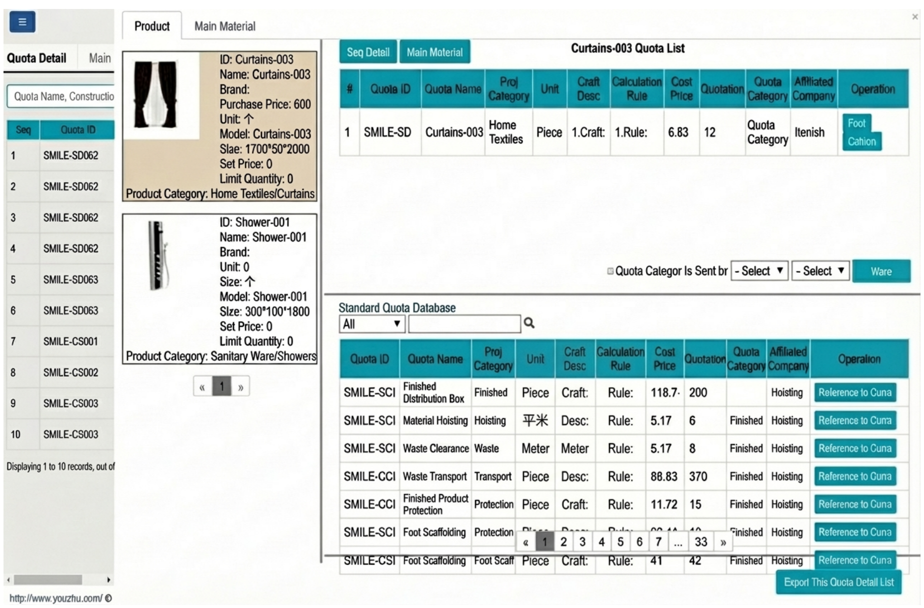

Figure 11: Figure 6