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Development of Defect Management In Construction Using Bim Technology

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Abstract
General contractors frequently use defect management (DM) for quality inspection (QI) to improve construction management of building projects. However, there are substantial problems with construction DM in common practice that have an impact on quality inspection. These problems include drawn-out processes, redundant data entry, complication, and ineffective information management. This research suggests a novel and useful method that applies Building Information Modelling (BIM) technology to quality inspection and defect control in recognition of these construction DM challenges. In order to define 3D object-oriented CAD, BIM specifically digitally contains the precise geometry and pertinent data required to support building constructions. This study suggests a BIM-based Defect Management (BIMDM) system used by on-site quality managers during the building phase using BIM technology. The desired strategy combines web and BIM technologies in the BIMDM system to visualize and assess defect data in real time at the project site. The well managed status and outcomes of the corrective actions are what are expected to happen. The BIMDM system is used in a particular case study of a construction project in Taiwan to validate the suggested strategy and show how effective defect control practice is. On-site quality managers are better equipped to track and control BIM model problems with the help of the BIMDM system thanks to precise records and pictures. The study's combined findings show that, when BIM and web technologies are merged, a BIMDM-like system can function as a powerful visual defect management platform. The benefit of the BIMDM system is that it facilitates simple quality inspection while recognizing and communicating in the 3D BIM environment, as well as enhancing defect management efficiency for on-site quality engineers and managers. As a result, authors anticipate that the implementation of the proposed BIMDM would greatly benefit on-site quality engineers and managers in their ability to organize and manage defect management tasks when using BIM technologies in the future.
Keywords: *BIM (building information modelling), information system, quality inspection, defect management.*

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I. INTRODUCTION

A crucial strategy in construction management's production phase is defect management (DM). Construction DM is used to find issues that do not comply with design criteria or specifications in the as-built or construction quality assessment phase. These problems frequently include "wrong wire installation," "unfinished partition corners," and others. DM is often carried out as part of punch list verification in the last stages of construction. Additionally, mobile technology have only had a limited impact on construction DM, aside from the more broad field of construction progress management. Construction DM is widely acknowledged as the most important quality management method in construction management. It is the process control for locating, documenting, and reporting flaws that do not meet the design objectives. The existing method of defect management leads to lengthy processes and mainly relies on duplicate data entering. Information delays in the design and construction processes, as well as misunderstandings among the various stakeholders participating in these processes, are frequently caused by the absence of efficient design collaboration between the construction site and the off-site design office.

Managing quality inspection (QI) work effectively can be extremely difficult in a construction building owing to unforeseen conditions and participants' comprehension level. For example, on-site quality engineers find it inconvenient to handle QI work by relying on paper-based documents. Furthermore, these engineers claim it is formidable to refer to the QI record for DM for determining the defect location based on 2D drawings. Unlike in the manufacture industry, information technology is applied limitedly in construction, and is mostly managed by human labor, which is inefficient and sometimes error-prone. On-site quality engineers usually refer to information such as specifications, checklists, maintenance reports, and maintenance records; however, they must record inspection (such as inventory confirmation) and QI results on hard copies in the site office. Such means of communicating information between an on-site office and a construction site are ineffective and problematic. According to the QI survey findings surrounding defect management of buildings in India, the primary defect issues encountered during the construction phase are as follows: (1) lack of QI operation efficiency, especially in document-based media in the defect management QI process; (2) failure to properly manage quality defects effectively during the construction phase; (3) difficulty tracking relevant history defect information based on the tradition 2D drawings at the construction site; (4) lack of complete records provided for each defect; and (5) few effective platforms to assist on-site quality managers to improve quality inspection and defect management work effectively. The performance of defect management can be enhanced by using BIM and web technologies to share and communicate defect information effectively. This study presents a novel approach called BIM-based Defect Management (BIMDM) system for on-site acquisition and tracking of defect and QI information in a commerce building. The BIMDM system is facilitated through the use of webcam-enabled tablets in a DM information sharing platform for on-site quality engineers and manager.

1.1 BIM-BASED DEFECT MANAGEMENT

Regarding the management of construction defects, there are a number of linkages between defects and CAD that force engineers to handle faults associated with CAD-based environments. Therefore, the main goal of the project is to provide a BIMDM system for the involved engineers to make updating and transferring flaws within the 3D CAD environment easier. The suggested unique technique uses BIM-based markable faults to improve the efficiency of exchanging and tracking defect information. Applying the DM method to locate, monitor, and control BIM-based markable defects will help participants improve quality management while reducing rework and encouraging positive change. The proposed DM technique contains four steps, which are as follows: discovering flaws, recording defects, responding to defects, and closing defects. Each phase is outlined briefly as follows.

Table 1: Description of Construction DM Phase.

PHASE	DESCRIPTION
Identifying Defects Phase	To identify the new or existing defect issues in quality control
Tracking Defects Phase	To ensure that the defect is identified and tracked for all related participants
Solving Defects Phase	To encompass request, response and tracking processes among all participants
Recording Defects Phase	To record the processes related to an identified defect issue
Closing Defects Phase	To confirm a defect issue without further issue identification or tracking

1.2 SYSTEM IMPLEMENTATION

In the study, the conceptual system architecture is created to support the BIMDM system (Fig.1). The conceptual structure of the BIMDM system content aims to raise the efficiency of DM projects built on the BIM platform. The conceptual model contains data and information on associated faults, including several sorts of defect contents that boost the flexibility and practical applicability of the BIM-based DM process. In order for a mix of contents and functionality to support the information, the numerous BIMDM system flaws must be assessed and combined. The system is built to accommodate all functions offered by current, cutting-edge DM and web communication tools. Text, images, digital documents, and other media may all be included as attachments.

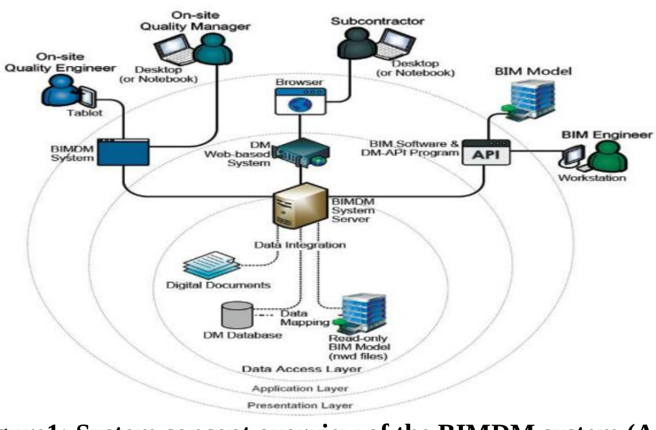

Figure1: System concept overview of the BIMDM system (Azhar, 2011)

The on-site quality manager, BIM engineer, on-site quality engineer, and subcontractor areas are the four user areas that make up the BIMDM system. The BIMDM system has password protection. In this study, defect information, such as defect issue descriptions, defect photographs, defect records, and defect reports, is captured and stored using the BIM in the BIMDM system. The BIM model files were created and maintained using Autodesk Revit. The BIM models of the flaws were integrated and read using Autodesk Navisworks. The Autodesk Navisworks application programming interface (API) and the VB.NET programming language were used to integrate the data with the BIM models. Using Navisworks API, the BIM models of defects and DM data were combined to create the BIMDM system.

1.3 SYSTEM DESIGN

BIM technology is used in the BIM models to assist on-site quality engineers in managing QI activities. On-site quality engineers and managers can resort to defect information such as defect subject, defect detail description, defect photographs, QI history information, and defect improved information by clicking on BIM location maps and accessing the related BIM model. Furthermore, traditional 2D drawings that have made it impossible to demonstrate the vertical placement or position of faults can be improved with the help of the BIM model's flaws tags. BIM technology can improve DM work and offer precise QI information sharing in this investigation. An integrated web platform may connect all the QI data on the construction site, enhancing the efficiency of the DM procedure.

A mobile devices subsystem, a DM hub centre subsystem, a DM Web-based portal subsystem, and a DM-API subsystem make up the BIMDM system. Significantly, the DM hub centre subsystem and the Web-based portal subsystem run on the server side, while the mobile devices subsystem and the DM-API subsystem are situated on the client side. Below is a synopsis of each subsystem. the construction site to increase the DM process' efficiency.

1.3.1 Mobile Device Subsystem

The BIMDM system utilizes two mobile devices. The tablets with webcams are the Acer Iconia W700P and the Microsoft Surface Pro. The Windows 8 operating system is used by both tablets. All tablet data is transmitted directly over the Internet through Wi-Fi or 3G between the client and server sides.

1.3.2 Hub Center Subsystem

The DM hub centre is a resource in the BIMDM system that all participants can access to get the QI data they need for DM right now. On the Internet, users can access a variety of data and services using a single front-end. For instance, on-site quality engineers can securely log on to the DM hub centre and access the most recent QI result data. The status of the QI, its results, and numerous other DM-related information can be found by on-site quality management. In a centralized DM database, all QI-related data that is collected within the DM hub centre subsystem is kept. Depending on their access rights, any subcontractor and supplier involved in quality control can update the necessary QI information using the DM hub centre subsystem.

1.3.3 Web-based portal subsystem

All subcontractors react to the DM web-based portal subsystem, which is a browser-based portal within the DM system, with the solved defects problem and the responded defects result going to the on-site quality manager. For instance, subcontractors can securely view the most recent QI defect result data by logging via the DM web-based portal. The subcontractor has the ability to update the results, status of problems solved, and numerous other QI-related information. A centralized DM database houses all QI-related issues and response data involving subcontractors.

1.3.4 API subsystem

In order to let the BIM engineer export the central BIM models into read-only BIM models (NWD files) and automatically upload them to the BIMDM system, this study creates a DM-API subsystem. On the client side of the BIMDM system, read-only BIM models (NWD files) can be downloaded for use in QI and DM. The DM-API subsystem will automatically synchronize the most recent read-only BIM models if the central BIM model has been changed. Additionally, without directly accessing the central BIM models, all information of BIM components can be saved and changed in the read-only BIM models (NWD files). Four key roles—BIM engineers, an on-site quality manager, on-site quality engineers, and subcontractors—are involved in DM in the BIMDM system. This study makes use of a client-server system architecture to stop the DM operation from impacting the QI operation of the BIM models. All read-only BIM models (NWD files) in the BIMDM system are kept on the server.

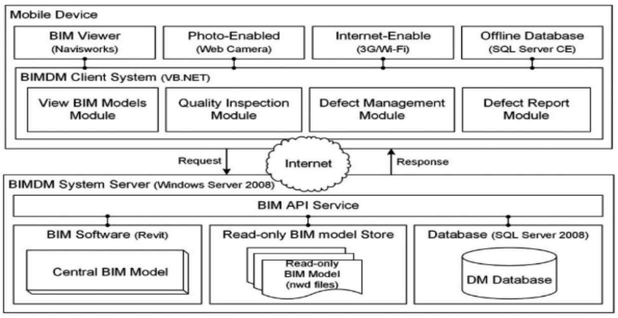

Figure2: System framework of the BIMDM system (Jagadeesh, 2019)

1.4 SYSTEM MODULES

1.4.1 View BIM models module

On-site quality engineers have access to examine and refer to BIM models at the construction site thanks to the view BIM models module. All on-site quality engineers can use this module to quickly access details about a defect's location and components, in particular the 2D/3D location, using a tablet.

1.4.2 Quality inspection module

Quality engineers on the job site can choose pertinent activities from lists in the tablet and identify those that don't pass inspection. The on-site quality engineers can modify the fault description, link the defect-related digital pictures, and identify the defect position using the BIM model immediately. By sending inspection findings and records integrated with BIM models between the tablet and BIMDM system by real-time synchronization, the module eliminates the need for duplicate data entry.

1.4.3 Defect management module

The on-site quality manager can track the status of quality inspections thanks to the DM module. The conveniently located module offers a mobile setting where the on-site quality manager and engineers may monitor and log all information pertaining to the state of the DM process straight from the tablet or BIMDM system.

1.4.4 Defect report module

Users can quickly use the defect report module in the BIMDM system to determine their needs and evaluate defect data in accordance with their specifications. Using commercially accessible tools (like PDF), all inspection findings can be presented alongside BIM models and extracted. General contractors keep authorized records, which can be extracted, compiled, and reported based on each faulty concern.

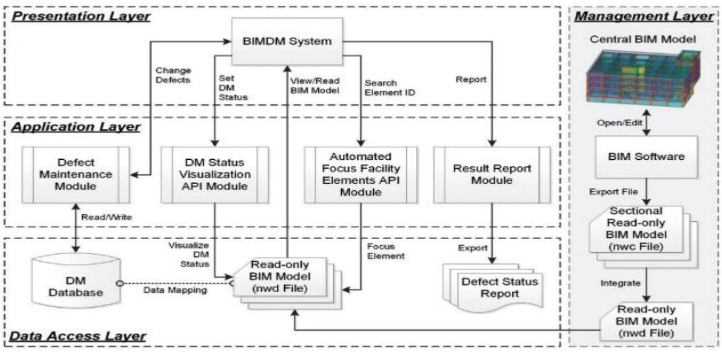

Figure3: System and modules framework of the BIMDM system (Bhuvanesh and Manoj ,2020)

1.5 SYSTEM INITIALIZATION PROCESS

Colour visualization in the BIM model can improve the DM status during QI activities. The DM status visualization API module is used to improve colour visualization. The BIMDM system may obtain the associated DM status from the list of defects in the DM database thanks to functionality that graphically displays the DM status for each identified fault. Furthermore, based on each DM state in the facilities, the BIM model can see various colours. Given this design approach, the BIMDM system simplifies more intricate DM operational operations. Each defect form will display the historical data, the status, and the condition of the selected defect by clicking the BIM-based defect maps.

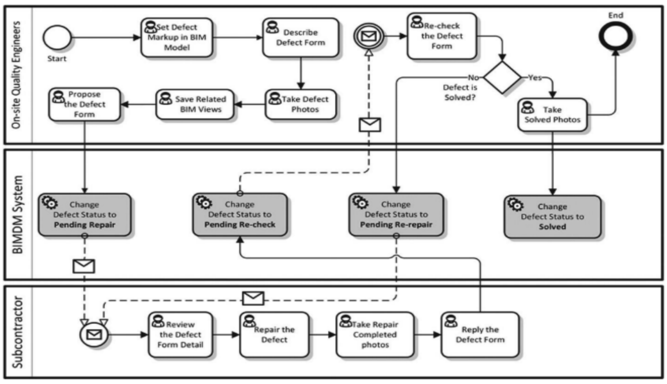

Figure4: Flowchart used in the BIMDM system (Bhuvanesh and Manoj ,2020)

The BIMDM system's ability to offer customers an intuitive visualization for managing QI and DM activities is one of its key features. The suggested method offers a practical way to update the DM information synchronization and QI information of the BIM model. Finally, based on recommendations from the quality engineers and managers on-site, the system interface design is adjusted for simple and efficient deployment.

II. CASE STUDY

In the scenario that follows, a company establishing offices in India wanted to improve quality defect management and manage faults more effectively. Usually, quality engineers on-site carried out the QI job. Although a defect management system had been built for information management, the majority of defect inspection activity was paper-based and documented by repetitive manual entry. In this study, DM for QI work of building projects is operated using a BIMDM system, specifically during the latter stages of the construction phase. The general contractor developed each BIM model. In order to check off items on the punch list during the last stages of construction, we employed the BIM models again. Less rework was produced, and QI output increased. During the final phases of the construction phase, the use of BIM models successfully improved defects management. The BIMDM system was used by the on-site quality engineers and manager to improve defect management for the case study's quality inspection of building projects. All of the faults were found during the period of identifying them by the project managers or other accountable participants. The engineer who initially located and edited defects in the BIM-based markable defects that were associated with interior decoration flaws. These flaws featured details of issues with the interior design as well as pictures of the flaws. This engineer also gave participants a task to find and follow BIMDM system flaws. Finally, this engineer approved BIMDM system using BIM-based markable flaws.

The system displayed the most recent status and outcome for each defect when the processed defect was tracked. By clicking on defect visual components in the BIM-based defects maps, engineers had easy access to linked defects. In order to prevent duplication, every flaw was also stored in the main database. Following project manager permission, relevant parties who were involved in the interior decoration faults documented their observations in the BIMDM system. Four engineers presented the most recent defect information and communicated their chosen defect issues in the BIMDM system during the defects tracking phase. As a result, parties accountable for a fault could communicate their justifications and observations to other participants. One project manager and two interior designers engineers discussed flaws using the BIMDM technology.

Two interior decoration engineers connected to the defect were contacted by a different senior engineer. The interior decoration engineers gave the engineer with a list of issues, and the engineer noted the defects (including descriptions, digital images, and relevant documentations). All records of the defect-processing steps were continuously kept and tracked during the recording and tracking phase. The BIMDM system tracked and highlighted defects that did not receive a response or were not processed in a timely manner in red. Additionally, throughout the period of reacting to defects, project managers and other involved parties were able to monitor and manage all finished or processed faults. This engineer resolved the defects issue and responded to the on-site quality manager with the defects outcome, presenting the on-site quality manager's defect records that were recorded and discussed. This was done after obtaining comments and assistance from all relevant participants. This engineer closed the accepted and confirmed defect case during the defects closing phase. After the approval procedure was finished, the defect status was updated and marked as defect closure in blue in the BIMDM system.

III. FIELD TESTS AND RESULTS

Verification and validation tests were run during the field trials to gauge how well the system worked. While validation gauges the system's usefulness, verification seeks to determine whether the system functions as intended by the design and specification. The BIMDM system's ability to carry out the tasks outlined in the system analysis and design was tested as part of the verification process. Selected people were asked to utilize the system and respond to a questionnaire as part of the validation test. The evaluation exam included 24 participants in total. Users of the system were requested to rate the circumstances of system testing, system function, and system capability individually, in contrast to the conventional paper-based defect management technique, in order to assess system function and the degree of satisfaction with the system's capabilities. This module made it possible for engineers to share defect information with the BIMDM system without having to undertake any more work to finish the documentation after the data gathering process. Results of a management survey showed that 85% of respondents were satisfied with monitoring and process management procedures. On the other hand, 26% of users reported having some trouble operating the BIM models reader used by on-site quality engineers, such as Autodesk Navisworks. From a real-world case study application, the BIMDM system's benefits and drawbacks are noted. The case study concludes by highlighting the potential for visual quality inspection to change the way construction defect management is done in the real world. Through the user satisfaction survey, feedback for upcoming BIMDM system upgrades was also gathered from the case participants.

Table 2: System evaluation results

System Evaluation Item	Standard deviation	Average rating
Application to construction industry	0.76	4.42
Ease of use	0.55	4.17
User interface	0.47	4.33
Overall system usefulness	0.64	4.42
Ease of locating defect information	0.72	4.25
Improves defect problem tracking	0.64	4.58
Reduces communication problems	0.37	4.83
Enhances visual defect management	0.49	4.58
Enhances defect problems illustration	0.37	4.83
Reduces data re-entry problems	0.47	4.67

1: Strongly disagree; 2 Disagree; 3: Neutral; 4: Agree; and 5: Strongly agree

The overall conclusion suggests that the BIMDM system is seen as being well designed and has the potential to streamline the currently drawn-out processes for construction quality assessment. The defect management module's over 91% satisfaction rate demonstrates its value in supporting quality inspection at the construction site. The quality inspection module's popularity among the on-site quality engineers who utilized it to instantly access visual quality inspection is evidenced by its 88% satisfaction rate.

IV. CONCLUSIONS

In the case study, the implementation of the BIMDM system aided in streamlining the quality inspection and defect management procedures for an Indian commercial building. This study showed, based on experimental findings, that BIM technology has a substantial potential to improve quality inspection work in defect management. On-site quality engineers were able to follow and manage the full quality inspection process with the help of the integration of BIM and web technology. The combined results showed that the BIMDM system can be a valuable platform for BIM quality inspection and defect management when compared to previously employed techniques. The proposed method has shown good results and a large potential for use in equipment and facility fault control in construction buildings, despite the difficulties mentioned above. The efficiency of quality inspection and fault management is increased and improved in an Indian commercial building by integrating automatically identifying technology. This study introduces the BIMDM system, which combines BIM and online technologies to enhance the efficacy and practicality of QI and DM of construction projects. The system enables synchronous communication between a worksite office and a construction site. The BIMDM system has the ability to develop novel procedures for defect management and construction quality inspection in a BIM visualisation environment when used for defect management. The BIMDM system's real-time defect data exchange between a construction site and a jobsite office may lessen duplication, improve performance, and prevent a lack of shared understanding among participants.

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