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# Development of a BIM-Integrated Quality Management Information System in the Defect Management Process to Improve Quality Assurance Efficiency and Effectiveness

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**Abstract**

This study aims to identify the capability gaps of the existing dashboard in supporting defect management and to analyze the potential contribution of Building Information Modeling (BIM) by formulating a conceptual model for QMIS-BIM integration. This research adopts a case study approach at PT X through archival analysis, questionnaire surveys, and expert validation using the Delphi method. The data were analyzed using descriptive statistics to evaluate the existing conditions, as well as Structural Equation Modeling–Partial Least Squares (SEM-PLS) to examine the structural relationships among the research variables. The findings indicate that QMIS serves as the core integration system that connects organizational policy and culture, BIM technology, and defect management activities within a unified digital framework. The output of this study is a data integration-based conceptual model developed from the existing dashboard framework as a strategic foundation for the future development of a QMIS-BIM platform. The proposed model is intended to shorten the defect handling cycle, improve the accuracy of defect detection and resolution, and bridge communication and information distribution barriers within the defect management process. Therefore, QMIS-BIM integration is expected to improve the efficiency and effectiveness of quality assurance in PT X's construction project implementation.



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## 1 Introduction

The Indonesian construction services industry continues to face significant challenges in improving competitiveness, quality, and operational efficiency. Construction is a heterogeneous industry, encompassing a wide variety of work across many different industrial sectors. Construction work involves numerous participants (design consultants, contractors, specialists) under the auspices of temporary organizations that are valid until the end of the specified contractual period (Warmerdam & Lingard, 2017; Turk, 2020; Nugraheni et al., 2021). The increasing complexity of construction projects further elevates the risk of quality non-conformities, particularly in large-scale and design-build projects.

In Indonesia, complex construction work is generally associated with high-risk activities, the use of advanced technology, specially designed equipment, technical uncertainty, unforeseen conditions, and/or project values exceeding IDR 100 billion. PT X, as a state-owned construction service provider with large business qualifications, operates within this market segment. In 2025, all new contracts obtained by PT X were valued above IDR 100 billion, while design-build contracts accounted for nearly 40% of the total contract value. This condition indicates that PT X manages projects with a high degree of complexity, requiring a more systematic strategy to ensure quality performance.

The business continuity of a service provider does not only depend on its ability to operate efficiently (Nugraheni et al., 2021; Braglia & Frosolini, 2014) but also on the ability to effectively improve performance in producing quality infrastructure. In this context, quality management is an important aspect in maintaining a company's competitiveness, especially in complex projects that have a close relationship between design, implementation, quality control, time and cost.

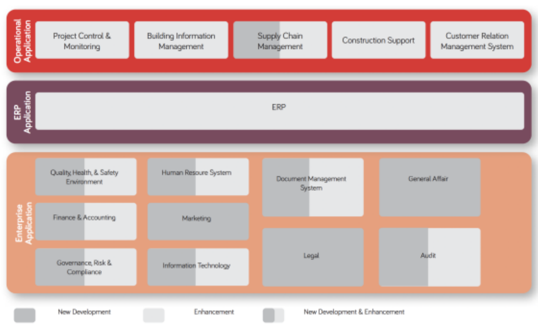



Figure **Error! No text of specified style in document.**. Information Technology Architecture Framework of PT X (2024 Period)
Source: Company Documents of PT X (2024)

As a strategy to achieve operational excellence, PT X has implemented digitalization through Big Data and Intelligent Dashboard initiatives. One of the systems used in quality management is the QHSE V2 Information System, or SIQHA, which functions as an enterprise-level application for recording, reporting, and monitoring quality-related information. Meanwhile, Building Information Modeling, or BIM, functions as an operational application that supports modeling, visualization, technical coordination, and project information management. Currently, both have important roles in supporting business processes, but are not yet fully integrated into one workflow, especially in the realm of defect management processes.

Although SIQHA and BIM both contribute to PT X's business processes, they currently operate within separate workflows and have not been fully integrated, particularly in the defect management process. This condition may limit the effectiveness of quality information management, especially in projects with high complexity and intensive coordination requirements. At the same time, PT X's financial performance in 2024 showed a decline compared to 2023, including decreases in operating revenue, gross profit, and operating profit, accompanied by a significant increase in operating expenses over the previous five years. This is important because defects in construction work have the potential to incur direct costs in the form of repair and rework, as well as indirect costs in the form of delays, wasted resources, increased coordination requirements, and potential claims. These conditions highlight the need to evaluate the efficiency of operational processes, including quality control and defect handling. Therefore, an evaluation of the capabilities of the existing dashboard in supporting the defect management process is necessary.

*Defect* has a negative impact that must be addressed through repairs or rework on affected items, which increases costs, time, resources, and manpower, which are forced to be allocated to the rework. In studies conducted by previous researchers, defects in construction projects require implementers to allocate rework costs, which cost at least 5% of the total project cost (Hwang, 2009). In other cases that occur at the national level, delays and inaccuracies in handling defects often result in construction failures. Not only does it have implications for the cost aspect, but defects also pose a challenge to fulfilling the time aspect. In addition, delays or inaccuracies in defect handling may affect project completion, quality compliance, and even construction safety. Regulatory provisions also emphasize that work handover may be postponed when quality defects or functional test results do not comply with contractual specifications. Therefore, defect management must be treated as a strategic priority in improving construction quality and company competitiveness.

Reflecting on the principles of Industry 4.0, the appropriate definition to describe the shift in the meaning of construction business processes that are adjusted to these principles is in the form of an organization of production processes based on technology and devices that are autonomously connected to each other along the production value chain (Carlberg, 2016). In the context of PT X, the SIQHA dashboard is a tool or facility that facilitates the achievement of solutions for operational work processes and procedures in quality management and assurance. Meanwhile, BIM plays a role as a system, management, method, or sequence of work for a project. With the existence of very diverse tools according to their respective specializations, interoperability becomes another issue on its own to address (Turk, 2020). In quality management, information such as quality reports, BIM models, inspection checklists, field documentation, and follow-up records may be stored across separate platforms. This separation can make information difficult to trace, slow to update, and vulnerable to miscommunication. Previous studies have also identified limited information from past projects and communication failures among stakeholders as key causes of recurring defects.

Table 1
Summary of Causes of Construction Project Defects

| |
|---|
| *Suboptimal knowledge transfer* |
| Communication failure among the responsible parties |
| Incomplete documentation and reporting |
| *Poor data handling* |
| *Low reliability and responsiveness* |
| *Prolonged and ineffective decision-making* |
| Ambiguity of technical provisions |
| Unclear policies regarding defect tolerance |
| Inaccurate implementation method |
| *Poor workmanship and the use of inappropriate materials* |
| Inadequate human resources and client management |
| Poor teamwork structure |
| Lack of engagement |

Source: Mahmood (2008); Ågren (2015)

In practice, the integration of other digital technologies in the QA realm is generally still at a very low level of technological readiness, with limited implementation and evaluation (Ghansah & Edwards, 2024). It was identified that the lack of information regarding previous projects was the main cause of the existence of recurring defects in building construction projects (Love, 2009). Defects are caused by communication failures between stakeholders in the project (Wang, 2007). Transparent communication and collaboration between the parties involved in a project can increase the level of synergy so that the quality management process can run smoothly (Kubicki et al., 2019). Collaboration between project stakeholders is limited when communication tools rely on 2D and 3D media due to limited spatial representation. Therefore, to support closer collaboration between internal and external stakeholders, a specific strategy based on intuitive cooperation is required (Wang, 2007). The following are several issues in the implementation of defect management and quality supervision from several previous studies:

Table 2
Defect Management and Quality Supervision Issues

| No | Issues/obstacles |
|---|---|
| 1 | Lengthy paper-based inspection procedures and labor-intensive manual data entry. (Jabbar & Nayar, 2022; Wang & Yu, 2024; Kang, 2025) |
| 2 | Difficulty in tracing the position or location of defects. (Jabbar & Nayar, 2022; Wang & Yu, 2024) |
| 3 | Communication difficulties between the office and the field personnel. (Jabbar & Nayar, 2022; Wang & Yu, 2024) |
| 4 | Loss of historical records related to defect findings. (Jabbar & Nayar, 2022; Wang & Yu, 2024; Ghosh & Karmakar, 2025) |
| 5 | Inconsistency in quality standards. (Chen, 2014; Kang, 2025) |
| 6 | Difficulty in tracing the parties responsible for identified defects. (Kang, 2025) |
| 7 | Visualization limitations due to reliance on 2D image visualization. (Jabbar & Nayar, 2022; Wang & Yu, 2024) |
| 8 | Slow and reactive evaluation and decision-making processes, rather than proactive ones. (May et al, 2022; van Besouw et al, 2021) |
| 9 | Inefficiencies and data security risks associated with manual data distribution. (Ghosh & Karmakar, 2025) |
| 10 | Non-streamlined defect handling processes. (Ghosh & karmakar, 2025) |
| 11 | Vulnerability to data manipulation. (Ghosh N Karmakar, 2025) |
| 12 | Absence of a centralized system for multi-project supervision. (Wang & Yu, 2024) |

Source: Jabbar & Nayar, 2022; Wang & Yu (2024); Kang (2025); Ghosh & Karmakar (2025); May et al. (2022); van Besouw & Bond-Barnard (2021), revised (2026)

Based on these issues, this study aims to examine the opportunity to develop PT X's existing Quality Management Information System, namely the SIQHA dashboard, to improve quality assurance performance through integration with BIM. The study considers several influential variables, including organizational policies and culture, information and communication management systems, conventional defect management processes, and BIM with other supporting technologies (Meiriza & Latief, 2025). Through this approach, the research is expected to contribute to the development of a more integrated, efficient, and effective defect management process in construction quality assurance.

## 2 Materials and Methods

This study employed a case study approach supported by archive analysis and survey methods. The case study focused on the implementation of the SIQHA dashboard-based defect management at PT X, while archive analysis was conducted using literature, regulatory documents, quality standards, company procedures, and previous studies. The survey was used to examine the influence of Quality Information Management System (QMIS), organizational policies and culture, defect management, and BIM with supporting technologies on the efficiency and effectiveness of the quality assurance process.

The research was conducted in two stages. The first stage evaluated the existing implementation of QMIS and BIM at PT X by comparing current practices with benchmarks derived from literature, regulations, standards, and company documents. This stage aimed to identify implementation gaps and formulate priority development needs. The second stage developed a proposed BIM-integrated QMIS model by incorporating best practices from previous studies and BIM as a supporting technology to address limitations in the current defect management process.

In general, there are four independent variables used in this study: Quality Information Management System (QMIS) (X1), Organizational policies and culture (X2), Defect Management (X3), BIM and technology (X4), on the efficiency and effectiveness of the quality assurance process (Y). In the research model structure, several variables act as mediating variables, especially QMIS (X1) and defect management (X3) because both of them bridge the influence of other variables on the efficiency of the QA process. QMIS is positioned as a core system that transforms the quality process from a manual and fragmented process to a more digitalized, structured, and traceable one.

Meanwhile, defect management is positioned as the main operational process that becomes the arena for implementing quality functions.

Two closed-ended questionnaires were developed. The first questionnaire addressed RQ1 by evaluating the existing condition of QMIS and BIM implementation, including BIM maturity level assessment. The second questionnaire addressed RQ2 by measuring respondents' perceptions of the relationships among constructs in the proposed BIM-integrated QMIS development model. Respondents were grouped based on work placement and organizational level, consisting of office-based managerial personnel, office-based staff, project-based managerial personnel, and project-based staff.

Primary data were collected through questionnaires distributed to respondents involved in quality management, defect management, and BIM implementation. Secondary data were obtained from literature, regulations, quality standards, company documents, and relevant technical references. Data analysis was conducted in two stages. Descriptive statistics were used to analyze the existing implementation conditions for RQ1, while Structural Equation Modeling–Partial Least Squares (SEM-PLS) using SmartPLS 4.0 was applied for RQ2 to examine the relationships among variables and their effects on the efficiency and effectiveness of the quality assurance process.

## 3 Results and Discussions

*Expert Data Collection*

Table **Error! No text of specified style in document.**
Research Expert Profile

| No | Expert | Placement | Position | Experience | Education |
|---|---|---|---|---|---|
| 1 | P1 | Project | *Project Manager* | 12 years old | S2 |
| 2 | P2 | Project | *Project Manager* | 15 years | S2 |
| 3 | P3 | Project | *Project Manager* | 13 years old | S2 |
| 4 | P4 | Office | Manager of QHSE Bureau & Building Department System | 20 years | S2 |
| 5 | P5 | Office | *Manager* Operation | 21 years | S2 |

Source: Author's Processed Data (2026)

A comprehensive overview of the experts in this study is that they are professionals involved in building construction projects with more than 10 years of work experience in the construction sector with a minimum of a Bachelor's degree (S1/D4) education. The experts are employees of PT X to ensure relevant input and are in accordance with PT X's current operational conditions.

There are two distributions of expert populations, where 3 (60%) experts come from the project environment, and 2 (40%) experts from the office environment. This composition shows a relatively balanced distribution so that it is able to represent two perspectives in the implementation of building construction, namely from the field operational perspective and the managerial-organizational perspective.

The experts' work experience spanning 12 to 21 years also demonstrates their long-term exposure to the dynamics of building construction projects, including challenges in quality control, inter-stakeholder coordination, information management, and field problem-solving. In terms of educational background, all experts exceed the established criteria, which include a master's degree (S2), and are therefore expected to possess strong analytical skills in assessing the suitability of research concepts, variables, and indicators to the context of field implementation and operations.

Based on this description, the characteristics of the expert respondents used in this study strengthen the credibility of the validation process, because they are supported by a combination of substantial professional experience, relevant job positions, and adequate levels of education.

*Respondent Data Collection*

Table 5
Profile of Questionnaire Respondents

| Demographics | | Amount | % |
|---|---|---|---|
| ***Gender*** | Man | 58 | 52.3 |
| | Woman | 53 | 47.7 |
| **Age** | 17 - 25 Years | 24 | 21.6 |
| | 26 - 41 Years | 65 | 58.6 |
| | 42 - 55 Years | 22 | 19.8 |
| **Last education** | D3 | 28 | 25.2 |
| | S1 | 62 | 55.9 |
| | S2 | 20 | 18.0 |
| | S3 | 1 | 0.9 |
| **Title/position** | *HEADQUARTER* (Management Level): Quality policy makers at unit/division level (General Manager, Operational Manager, HSE/Quality governance, function heads related to quality systems) | 27 | 24.3 |
| | *HEADQUARTERS* (Staff Level): BIM & Systems (BIM Engineer/Coordinator, Digital Construction Team, Admin CDE/Platform, IT support) and QHSE (QHSE Coordinator & QHSE Staff) | 18 | 16.2 |
| | *PROJECT* (Management Level): Project management & controller (Project Manager, Project Engineering Manager, Project Production Manager, QHSE Coordinator) | 20 | 18.0 |
| | *PROJECT (Staff*Level): Field Operations (QA/QC Engineer, Site Engineer, Supervisor), Project BIM Coordinator, Project BIM Staff | 46 | 41.4 |
| **Work experience** | 1-3 years | 42 | 37.8 |
| | 4-7 years | 38 | 34.2 |
| | 8-15 years | 26 | 23.4 |
| | >15 years | 5 | 4.5 |
| **Involvement in QA/Defect Management process** | Sometimes Involved | 27 | 24.3 |
| | Highly Involved | 23 | 20.7 |
| | Involved | 61 | 55.0 |
| **Use of QMIS/quality dashboard** | Just view the report | 29 | 26.1 |
| | Active users | 42 | 37.8 |
| | Occasional user | 40 | 36.0 |
| **Use of BIM in projects** | Just look at the output | 28 | 25.2 |
| | Active users | 32 | 28.8 |
| | Occasional user | 51 | 45.9 |
| **Types of projects handled (last 5 years)** | Conventional | 45 | 40.5 |
| | Conventional and Design and Build | 14 | 12.6 |
| | Design / Design and Build | 52 | 46.8 |

Source: Author's Processed Data (2026)

A descriptive analysis of demographic characteristics was conducted to provide a comprehensive overview of the profiles of the 111 respondents who participated in this study. The gender composition showed a relatively balanced distribution, with 52.3% male and 47.7% female. In terms of age, the majority of respondents were in the mature productive age range, namely 26 to 41 years (58.6%), followed by the 17–25 age group (21.6%) and the 42–55 age group (19.8%). This demographic profile was supported by a very adequate level of formal education. More than half of the respondents (55.9%) had a bachelor's degree (S1), and the rest had postgraduate education backgrounds (S2 (18%) and S3 (0.9%) and diplomas (25.2%). This good level of education indicates that respondents have the intellectual and literacy capabilities to accurately understand the questionnaire instrument, thus minimizing the potential for response bias.

In terms of professionalism, the respondents' positions represented various managerial and operational levels, both within the project environment and at headquarters. The largest group held project-level staff positions, such as QA/QC Engineers, Site Engineers, and BIM staff (41.4%). This indicates that the majority of data came from field practitioners who deal directly with operational technical execution. However, the representation of management levels was also proportionally distributed, with 24.3% of respondents in unit/division level management at headquarters, and 18% in project management. Regarding length of service, most participants had between 1 and 7 years of work experience (72% cumulative), indicating that this study sample was dominated by mid-career individuals who already possessed relevant tactical and practical understanding of the construction industry.

The operational characteristics of the respondents also showed a high alignment with the research focus, particularly regarding quality management and technology adoption. The majority of respondents actively participated in Quality Assurance (QA) and Defect Management processes, with 55% stating they were involved and 20.7% were very involved. This practical exposure was directly proportional to their interaction patterns with management information systems; 37.8% were active users of Quality Management Information Systems (QMIS) or quality dashboards, and 36% were occasional users. In the context of Building Information Modeling (BIM) utilization, the majority of respondents had good functional literacy, with 45.9% using it occasionally and 28.8% being active users. This data confirms that respondents not only understood the concepts theoretically but also had direct technical experience with the digital tools studied.

Based on their portfolio track record over the past five years, respondents' experience spans a wide range of project delivery methods. 46.8% of respondents are accustomed to handling projects using the Design and Build method, while 40.5% have handled conventional projects, and 12.6% have been involved in both types of projects. Overall, the combination of strong educational backgrounds, comprehensive field experience, and direct interaction with quality management systems and BIM makes this group of respondents highly representative. These characteristics ensure that the empirical data obtained have high practical validity and are credible for further evaluation at the measurement and structural model testing stages.

*Data Result Analysis*

*RQ 1 Results*

The indicator with the lowest score for each dimension was selected for further analysis. Low-scoring indicators were selected because they represent the weakest and least optimal aspects of each dimension. Therefore, these indicators can be positioned as critical points indicating a gap between current practices and ideal requirements in implementing defect management and utilizing BIM.

Table 6
Existing Condition Mapping Table

| | |
|---|---|
| **Problem 1:** | **(X1.1.3) Data Management**- The system does not have a mechanism to prevent unauthorized data changes, and there are no access restrictions set according to user roles. |
| | **Further observations in the field:** |
| | Based on observations made on the system, the division is defined as follows:<br>A. Guest: Can only view data according to the selected project.<br>B. QHSE Project: Responsible for reporting data from each project.<br>C. Project Manager: Responsible for scanning and verifying reports. |

| | |
|---|---|
| |  |
| | **Observation Conclusion:** |
| | User rights and access restrictions are defined but not clearly distributed and not well socialized. |
| | **Discussion:** |
| | Clear role differentiation supports data management, information distribution, statistical analysis, and the implementation of oversight and regulatory functions. Furthermore, role differentiation facilitates stakeholders' needs for uploading data, searching for information, providing responses, and filtering out information irrelevant to each role. (Van Besouw & Bond-Barnard, 2021). |
| | **Impact:** |
| | - Ambiguity of responsibility<br>- Weak access control<br>- Suboptimal flow of information between users |
| **Problem 2:** | **(X1.2.3) Procedure**– The system is not integrated with various supporting platforms (BIM, Office, other microservice platforms) |
| | **Further observations in the field:** |
| | The system has a file export feature in Excel (.xls) format. However, this data retrieval is merely a data conversion, not an integration into an active system/platform.<br> |
| | **Observation Conclusion:** |
| | There is no integration capability in the system with other software/platforms. |
| | **Discussion:** |
| | Seamless integration within digital workflows supports real-time, structured information flow. (Van Besouw & Bond-Barnard, 2021; Aranda, 2015) |
| | **Impact:** |
| | - Job redundancy<br>- Human error<br>- Inconsistency of information |
| **Problem 3:** | **(X.1.3.1) Resources**- The number of personnel and skill levels allocated to the project do not accommodate the current processes. |
| | **Further observations in the field:** |
| | The number of personnel and level of capability are considered inadequate because in current practice, existing personnel are forced to accommodate two different processes (conventional and digital). |
| | **Observation Conclusion:** |
| | Commitment to digitalization is still low, resulting in a double workload. |
| | **Discussion:** |
| | Reducing work steps through digitalization can increase productivity by automating repetitive tasks and reducing administrative workload. (Jabbar & Nayar, 2022) |
| | **Impact:** |
| | - Low work productivity |

| | |
|---|---|
| | - Delay of the overall process<br>- Not time efficient |
| **Problem 4:** | **(X1.4.4) Cost**- Quality cost reports cannot be broken down by period/area/job for trend analysis. |
| | **Further observations in the field:** |
| | There's a 'Cost & Value' loss page on the Dashboard. Its components are as follows:<br>- Total planned and actual completion costs<br>- Trendline graph of total planned and actual completion costs<br>- Grouping costs based on NC severity<br>- Total cost breakdown per period (monthly/annual)<br> |
| | **Observation Conclusion:** |
| | Aggregate cost data is available, but cannot be traced per work zone/location or work item, so HQ/head office operational visibility into the project is minimal. |
| | **Discussion:** |
| | Repair and rework costs are the main contributors to project financial losses (Ghosh & Karmakar, 2025), however, low drill-down capacity in terms of costs has the potential to cause root cause analysis failures, which lead to increased handling costs (Jabbar & Nayar, 2022; Chen et al., 2024) |
| | **Impact:** |
| | - Difficulty in evaluation<br>- Swelling of handling costs due to the inability to predict<br>- There is potential for subjectivity and data manipulation |
| **Problem 5:** | **(X1.5.3) Evaluation**- Reports generated by the system cannot be customized per needs (management, owner, contractor, regulator) |
| | **Further observations in the field:** |
| | Based on observations made on the dashboard, there is a standard format for retrieving data from data that has been inputted on the dashboard as follows: |

| NO | PERIODE | NAMA DEPARTEMEN | NAMA PROYEK | NOMOR PROYEK | TANGGAL KETIDAKSESUAIAN | NOMOR KETIDAKSESUAIAN | KRITERIA NC | NAMA PEMRAKARSA | DESKRIPSI KETIDAKSESUAIAN | STATUS |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | December 2024 | GEDUNG | Pembangunan Jalan Tol Ruas Sigli - Banda A | 2019171032 | 12/05/24 December 2024 | 002/2019171032/NC-HS/XII/20 | Minor : Unsafe | Putri Anggrayani | Tidak ada Baricade | closed |
| 2 | December 2024 | GEDUNG | Pembangunan Jalan Tol Ruas Sigli - Banda A | 2019171032 | 12/05/24 December 2024 | 001/2019171032/NC-HS/XII/20 | Minor : Unsafe | Putri Anggrayani | Pekerja kurang kesadaran untuk pe | closed |
| 3 | December 2024 | GEDUNG | Pembangunan Jalan Tol Ruas Sigli - Banda A | 2019171032 | 12/07/24 December 2024 | 003/2019171032/NC-HS/XII/20 | Minor : Unsafe | Putri Anggrayani | Pekerja tidak menggunakan APD | closed |
| 4 | December 2024 | GEDUNG | Pembangunan Jalan Tol Ruas Sigli - Banda A | 2019171032 | 12/12/24 December 2024 | 004/2019171032/NC-HS/XII/20 | Minor : Unsafe | Putri Anggrayani | material sisa yang terkumpul di bel | closed |
| 5 | December 2024 | GEDUNG | Pembangunan Jalan Tol Ruas Sigli - Banda A | 2019171032 | 12/17/24 December 2024 | 005/2019171032/NC-HS/XII/20 | Minor : Unsafe | Putri Anggrayani | crane tidak digunakan lag | closed |
| 6 | December 2024 | GEDUNG | Pembangunan Jalan Tol Ruas Sigli - Banda A | 2019171032 | 12/19/24 December 2024 | 006/2019171032/NC-HS/XII/20 | Minor : Unsafe | Putri Anggrayani | Orang kurang sadar dalam kebersil | closed |

| | |
|---|---|
| | **Observation Conclusion:** |
| | The system's ability to accommodate user needs is very limited. Data must be adjusted manually and independently by users. |
| | **Discussion:** |
| | The report customization feature is an important aspect for filtering information needs so that users can focus on their respective work portions without having to modify data manually (Wang & Yu, 2024). |
| | **Impact:** |
| | - The reporting process is slow and takes time and effort.<br>- High incidence of human error. |
| **Problem 6:** | **(X1.6.3) Learning Knowledge**– There is no feedback from internal/external audits recorded in the system and integrated into the latest SOP/ITP. |
| | **Further observations in the field:** |
| | The dashboard has not been reviewed or re-evaluated since its initial launch (2022). The |

| | |
|---|---|
| | dashboard implementation itself has been integrated into the company's SOP/Quality Management Procedures (Source: BP 025 QH 03 - Quality Non-Conformance Handling Procedure). |
| | **Observation Conclusion:** |
| | No internal/external audit trails were detected on the dashboard. No further development to adapt it to current user needs has been undertaken. |
| | **Discussion:** |
| | Periodic evaluation allows the system to continue to be adaptive and remain relevant in responding to challenges and changing project dynamics (Ghosh & Karmakar, 2025; Sihombing, 2024) |
| | **Impact:** |
| | - Lack of continuous improvement<br>- Low relevance and adaptation of the system to field dynamics |
| **Problem 7:** | **(X2.1.2) Government Policy**- System implementation takes into account government regulations governing the implementation mechanisms of QA and QC for design & build projects. |
| | **Further observations in the field:** |
| | No specific QA & QC implementation mechanism has been detected in coercive design & build projects. |
| | **Observation Conclusion:** |
| | QA and QC on design & build projects are standardized with projects using conventional methods. |
| | **Discussion:** |
| | The shifting roles and responsibilities in design & build projects require new layers of protection to ensure quality (Liu et al., 2022). |
| | **Impact:** |
| | - Workflow bottlenecks<br>- Delay of the overall process |
| **Problem 8:** | **(X.2.2.2) Quality Culture**– Lack of programs, training, socialization, and competency development related to the implementation of QMIS for quality management |
| | **Further observations in the field:** |
| | The SIQHA dashboard socialization was only carried out once during the first platform launch (in 2022). |
| | **Observation Conclusion:** |
| | Training, outreach, and competency development related to QMIS implementation for quality management are not conducted regularly, even with new users. New users must rely on company guidelines to operate the dashboard independently. |
| | **Discussion:** |
| | Efforts to educate stakeholders about the benefits, effectiveness, and efficiency through system implementation are needed to minimize worker rejection or resistance to technology (Ghosh & Karmakar, 2025).<br><br>Providing training programs is highly recommended so that workers are able to optimize the use of system functionality in the field (Ghosh & Karmakar, 2025). |
| | **Impact:** |
| | - Lack of user knowledge of the system<br>- Low concern to accommodate the process<br>- The system is not used as it should |
| **Problem 9:** | **(X2.3.2) Quality Maturity**- Companies are not adaptive to the adoption of innovation, change, and digitalization of business processes, including openness to accepting new technologies. |

| | |
|---|---|
| | **Further observations in the field:** |
| | In practice, commitment to digitalization is weak. Workflows are split and run separately: conventional processes and digital processes. |
| | **Observation Conclusion:** |
| | Resistance to abandoning old methods is still high despite calls for digitalization of procedures. |
| | **Discussion:** |
| | High organizational flexibility is achieved when readiness for change is the foundation of the company culture. Companies that proactively invest in change consistently align the technology they develop with business objectives (Razkenari & Kibert, 2022). |
| | **Impact:** |
| | - Low level of technology adoption<br>- The system is considered merely an administrative burden and not a solution instrument.<br>- Waste of investment due to underutilization of the developed system |
| **Problem 10:** | **(X3.1.2) Defect Identification Phase**- Visual aids are not available and do not facilitate identification of technical references, determining zones and areas affected by defects, and comparing between design and field conditions. |
| | **Further observations in the field:** |
| | Visualization assistance is essential, particularly during the "Verification of NC Reports" (BP 014 QH P03) process, to compare findings with technical references. The visualization assistance utilized is still through paper media (working drawings) obtained from the project's engineering division. |
| | **Observation Conclusion:** |
| | Confusion in technical references affects the quality of decision-making. The data used is potentially obsolete or unreliable. |
| | **Discussion:** |
| | Conventionally, identifying defects through paper drawings (2D) requires high spatial expertise and often leads to misinterpretation in the field (May, 2022). The availability of readily accessible technical references facilitates collaboration and improves understanding of defect acceptance parameters (Chen, 2014). |
| | **Impact:** |
| | - Benchmarking bias or the basis for rejecting/accepting the found items.<br>- High risk of misinterpretation and miscommunication |
| **Problem 11:** | **(X3.2.1) Defect Tracking Phase**- It is difficult to analyze the impact or effect of a defect finding to track the existence of other similar defects in the field. |
| | **Further observations in the field:** |
| | The preventive measures taken in current practice against the potential emergence of other defects in the field are through the process of "Analyzing the causes and determining preventive measures so that NC does not recur" after repairs are made to the defects found. |
| | **Observation Conclusion:** |
| | Current data analysis and tracking are not data-driven. They are reactive (because they are performed after a defect has been resolved) rather than proactive. |
| | **Discussion:** |
| | Through a proactive understanding of defect cause diagnosis, companies can take more targeted corrective actions and can quickly identify and eliminate the sources of defects (Chen et al., 2024). |
| | **Impact:** |
| | - Delay in carrying out "prevention"<br>- Potential recurrence of similar defects at the same/different locations<br>- Tracking duration becomes longer. |
| **Problem 12:** | **(X3.3.1) Defect Management Phase**- Handling of defects is not done in a timely manner according to the target |

| | |
|---|---|
| | **Further observations in the field:** |
| | In several observed sample cases, the duration of defect handling varied considerably. Some examples of repair work include:<br><br>**Project A**reported the NC Mayor on November 28, 2024 regarding casting work that did not meet quality requirements (porous) so that repairs were required.<br>- Completion plan on December 5, 2024<br>- Realization on December 30, 2024 after grouting and rework.<br>- The completion report was submitted on December 3, 2024 and verified by PM on December 3, 2024.<br>- The total completion time is 32 days, with the note that the PM has not yet verified the system after the repair work is complete.<br>The conclusion that can be drawn apart from the fact that the realization of the plan was missed is that the reported defect management process was not carried out in stages because PM verification was carried out before the completion of the work.<br><br>**Project B**reported NC Mayor on April 1, 2026 regarding the error of inappropriate installation of practical column reinforcement which has the potential to cause structural defects requiring repair.<br>- Completion plan on April 17, 2026<br>- Realization on April 18, 2026 after dismantling and reworking.<br>- The report was resubmitted on April 23, 2026 and verified by PM on the same day.<br>- Total completion duration is 22 days.<br>The conclusion that can be drawn is that there is a significant time gap from the time the defect is reported to the time the defect is closed. |
| | **Observation Conclusion:** |
| | Defect resolution in field practice is often hampered by several factors that lead to prolonged delays. This includes the lack of evaluation or feedback regarding the handling that has been carried out. |
| | **Discussion:** |
| | The use of QMIS in defect management reduces communication time, historical data retrieval, and document approval bureaucracy. With optimal use, historical data retrieval is 90% faster than manually sifting through piles of paper documentation. Communication of inspection reports is 79.3% faster because it eliminates the need for verbal communication, enabling faster decision-making. (Ghosh & Karmakar, 2025). |
| | **Impact:** |
| | - The workflow is not measurable and structured in stages. |
| **Problem 13:** | **(X3.4.3) Defect Documentation Phase**- Process automation does not improve administrative efficiency |
| | **Further observations in the field:** |
| | Process automation, which is intended to increase efficiency, is instead perceived as a waste of energy because field implementation of digitalization is not yet consistent. |
| | **Observation Conclusion:** |
| | The administrative burden is large and cannot be accommodated through the current process. Conventional practices are preferred. |
| | **Discussion:** |
| | QMIS absorbs much of the administrative, communication, and data management workload previously performed manually, freeing up time and personnel to focus solely on quality evaluation and defect correction. These efficiencies occur in:<br>- Filling out electronic checklists, attaching photos, and marking defect locations in real time using a dashboard on a device, thus eliminating duplicate data input (Lin & Fun, 2019; Ghosh & Karmakar, 2025) |

| | |
|---|---|
| | - Processing raw data into ready-to-use reports (visual dashboards, Gantt charts for scheduling, to recapitulation of cost estimation analysis and repair duration) without the need for manual calculations by staff. |
| | **Impact:** |
| | - Unreliable flawed documentation |
| **Problem 14:** | **(X3.5.1) Defect Closure Phase**- The defect repair verification process was not carried out carefully and accurately. |
| | **Further observations in the field:** |
| | Even with repairs being made to some defective items, not all approvals or closures are tracked by documentation. |
| | **Observation Conclusion:** |
| | Verification of repair results has not been running effectively. |
| | **Discussion:** |
| | A defect may only be officially declared closed when it is accompanied by an unmanipulated record (visual evidence, timestamp) (Jabbar & Nayar, 2022; Ghosh & Karmakar, 2025) |
| | **Impact:** |
| | - Administratively low closing rate<br>- Not all defect approvals and closures are documented by the system.→difficulty in conducting managerial evaluations |
| **Problem 15:** | **(X4.1.1)**The company does not have a documented BIM workflow used in the project. |
| | **Further observations in the field:** |
| | The BIM workflow is regulated in the company's BIM Manual, which covers: Introduction, management principles (tendering phase, implementation phase, handover phase), and BIM monitoring (introduction, maturity assessment). However, due to a lack of understanding of BIM in the field, it is often neglected, creating a fragmented workflow. |
| | **Observation Conclusion:** |
| | BIM workflows are defined but need to be further aligned to more optimally support project needs. |
| | **Discussion:** |
| | Without an integrated workflow, BIM will remain a static 3D design tool. BIM should not be treated as a mere repository or representation of reality. BIM-based Integrated Project Delivery transforms passive data into a proactive decision-making tool. (Jabbar & Nayar, 2022) |
| | **Impact:** |
| | - Process insynchronization<br>- There is a potential clash between BIM workflows and other divisions |
| **Problem 16:** | **(X4.1.5)**The company defines a primary BIM platform (CDE, authoring tools, coordination) but it is not used consistently by the project. |
| | **Further observations in the field:** |
| | Not all parties know about, or are able to utilize, the CDE platform or authoring tools for coordination. |
| | **Observation Conclusion:** |
| | The use of CDE and authoring tools is not yet evenly distributed. |
| | **Discussion:** |
| | The CDE serves as a central repository that synchronizes various IT ecosystems such as spatial data management systems, cost estimation, and scheduling (Yoon, 2025). |
| | **Impact:** |
| | - Implementation of unreliable information |
| **Problem 17:** | **(X4.1.13)**User access to the BIM system is not regulated through clear access rights. |
| | **Further observations in the field:** |
| | The availability of user access is adjusted at the time of project BEP submission, and |

| | |
|---|---|
| | agreed with the owner according to the project's needs and preferences. |
| | **Observation Conclusion:** |
| | Some parties are still unaware of the availability of BIM access. BIM utilization is limited to contractor operations. |
| | **Discussion:** |
| | In the concept of role differentiation, each permission and system entrance is specifically configured based on the level, department, and responsibilities of each stakeholder such as clients, consultants, project managers, BIM technicians, and subcontractors (Wang & Yu, 2024). |
| | **Impact:** |
| | - Ambiguity of responsibility<br>- Weak access control<br>- Suboptimal flow of information between users |
| **Problem 18:** | **(X4.1.16)**Project information exchange does not follow information structure standards (e.g. ISO 19650). |
| | **Further observations in the field:** |
| | Information exchange is organic and more tailored to project needs, but not dictated by any specific standards. The flow and frequency of information exchange are unclear. |
| | **Observation Conclusion:** |
| | Information standards are defined in the EIR but are not well socialized. |
| | **Discussion:** |
| | The absence of information structure will leave the team drowning in abundant but chaotic and useless information (ISO 19650). |
| | **Impact:** |
| | - Data is difficult to trace and utilize<br>- Inefficient and data-driven strategy setting<br>- The potential for misunderstanding and miscommunication between divisions in each project is high. |

Source: Author's Processed Data (2026)

Based on observations of the existing conditions, it can be concluded that the QMIS is available and used in operational processes. The system already has several basic features such as user role allocation, recording of non-conformity reports, cost recapitulation, and defect documentation. However, these functions still tend to be used as administrative and reporting media after the overall process is carried out conventionally in the field. This is evident from the still dominant practice of field inspections, direct communication, manual recording, and separate documentation that is then input into the QMIS as a form of administrative reporting fulfillment. Thus, the existing QMIS has not played its intended role.

Furthermore, the lack of evaluation and socialization of QMIS contributes to high user resistance in utilizing QMIS as part of technological innovation in the quality process. Users who do not gain an adequate understanding of the benefits, functions, and relevance of the system will tend to retain old methods that are considered more familiar. Moreover, the absence of periodic evaluation of the system based on user feedback risks creating a perception of the system as rigid, less responsive, and less relevant to the actual needs of the customer. As a result, QMIS tends to be perceived not as an active instrument that supports quality control and assurance, but rather as an additional administrative system that must be fulfilled after the conventional quality supervision process is carried out.

Although more readily accepted by users, observations have shown that the existing conventional defect management implementation also has its limitations. The process is still susceptible to differences in perception, the use of outdated references, and misinterpretations in understanding the relationship between defects, location, and design. Conventional defect management struggles to process historical data to understand recurring defect patterns, identify vulnerable locations, or predict the emergence of similar defects in other areas. This results in variable defect resolution times, a tendency to exceed established plans, and incomplete documentation of approvals or close-out statuses in the QMIS. Consequently, the process becomes less efficient, defect prevention is delayed, the potential for recurrence increases, administrative burdens increase, and defect closure rates decline.

The company has defined a BIM manual, BIM workflow, and platform usage requirements such as CDE and authoring tools. However, under existing conditions, the BIM process and quality management process remain separate. BIM has not been utilized as an information base to support defect identification, tracking, verification, and closure. BIM utilization remains dominant in certain operational aspects that do not directly intersect with the quality process, which can lead to fragmentation between design, quality data, defect data, and field implementation data.

Thus, the required development model direction is the integration of QMIS and BIM within a single digital workflow. The development model needs to be directed so that QMIS is not merely a medium for inputting reports, but rather an active instrument to support quality control supported by BIM technical capabilities. Integration with BIM is necessary so that every*defect*can be linked to model elements, work zones/locations, technical reference documents, handling costs, verification status, and repair history. Through this integration, the quality management process can shift from a conventional, reactive pattern to a robust, visual, real-time, documented, and data-driven system.

*Results Analysis (SEM-PLS)*

*Convergent Validity Test*

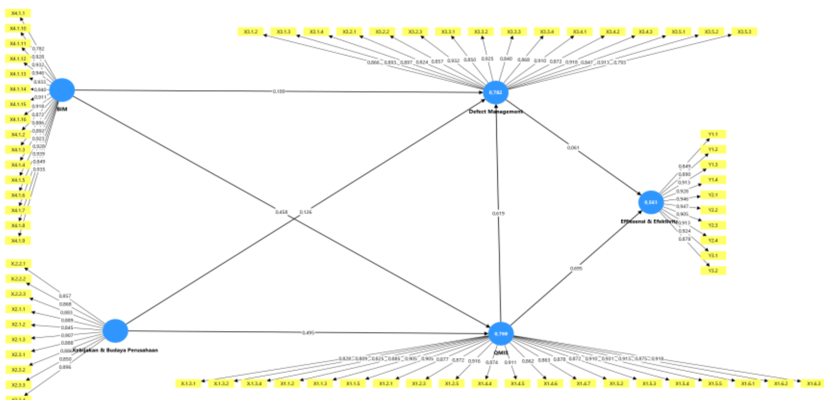


Figure 2. PLS Model Path
Source: Author's Processed Data (2026)

The initial evaluation of the measurement model (outer model) focused on testing the reliability of individual indicators represented by outer loading values. Guided by the PLS-SEM evaluation standards of Hair et al. (2022), an indicator is deemed to have an adequate level of reliability and is worthy of being retained in the model if it records an outer loading value greater than or equal to 0.708. Meeting this threshold is crucial because it indicates that a latent construct is able to explain at least 50 percent of the variance of the measuring indicator. The results of the algorithm's data extraction on all statement items from the five main constructs—QMIS, Corporate Policy & Culture, Defect Management, BIM, and Efficiency and Effectiveness—demonstrate very solid measurement performance, with all indicators confirmed to exceed the minimum acceptance criteria.

Specifically, the distribution of factor loadings from this research instrument is in a very high value range. The lowest outer loading value was recorded in indicator X4.1.1 (0.782) forming the BIM construct, while the highest absolute loading value was achieved by indicator Y2.2 (0.947) in the Efficiency and Effectiveness variable. Considering that none of the indicators had a value below the critical limit of 0.708, there was no need for an item elimination procedure (indicator removal) to improve the model's reliability. This empirical finding provides strong statistical confirmation that all observation items are highly reliable in reflecting their respective latent constructs, so that the architecture of this measurement model is declared valid and safe to proceed to the next evaluation stage, such as testing convergent validity (AVE) and internal consistency.

*Hypothesis Testing*

Table 7
R-Squared

| | *R-square* | *R-square adjusted* |
|---|---|---|
| ***Defect Management*** | 0.782 | 0.776 |
| **Efficiency & Effectiveness** | 0.561 | 0.553 |
| **QMIS** | 0.769 | 0.765 |

Source: Author's Processed Data (2026)

Structural model (inner model) evaluation focuses on assessing the model's explanatory capability, which is statistically measured through the coefficient of determination (R-squared). Guided by the PLS-SEM evaluation criteria formulated by Hair et al. (2022), R-squared values of 0.75, 0.50, and 0.25, respectively, represent substantial (strong), moderate, and weak levels of model prediction accuracy. This assessment is crucial for justifying how much of the variance of each endogenous latent variable is successfully revealed or predicted by the exogenous latent variables that precede it in the structural path constellation.

Based on the results of the test data extraction, the endogenous variables Defect Management and QMIS showed very satisfactory explanatory performance. The R-squared value for Defect Management was recorded at 0.782, while QMIS reached 0.769. Both achievements successfully exceeded the threshold of 0.75, thus being classified into the substantial category. Empirically, this figure interprets that 78.2% of the variation that occurred in Defect Management and 76.9% of the variation in the QMIS system can be comprehensively explained by the predictor constructs in the model. The remaining variance of both variables is the portion explained by other factors outside the scope of this study.

On the other hand, the endogenous variable Efficiency & Effectiveness recorded an R-squared value of 0.561. Referring to the guidelines of Hair et al. (2022), this result falls into the moderate classification because it is consistently above the 0.50 criterion. This means that this structural model is able to predict 56.1% of the variation in operational efficiency and effectiveness. As a robustness check, observations of the adjusted R-square values of the three endogenous variables (Defect Management = 0.776; QMIS = 0.765; Efficiency & Effectiveness = 0.553) show a very minor correction difference compared to the original R-squared value. The stability of this figure confirms that the structural model is free from indications of overfitting or bias that may arise due to the complexity of the number of predictors. Thus, overall, this model architecture is proven to have robust and reliable explanatory power.

Table 8
Path Coefficient

| **Hypothesis** | **Path** | ***Path Coefficient (O)*** | ***T-Statistics*** | ***P-Values*** | **Decision** |
|---|---|---|---|---|---|
| **H1** | Company Policies & Culture→QMIS | 0.495 | 4,744 | 0,000 | Accepted / Supported |
| **H2** | BIM→QMIS | 0.458 | 4,265 | 0,000 | Accepted / Supported |
| **H3** | QMIS→Defect Management | 0.619 | 4.79 | 0,000 | Accepted / Supported |
| **H4** | Defect Management→Efficiency & Effectiveness | 0.061 | 0.409 | 0.683 | **Rejected / Not Supported** |
| **H5** | QMIS→Efficiency & Effectiveness | 0.695 | 5,045 | 0,000 | Accepted / Supported |

Source: Author's Processed Data (2026)

Hypothesis testing on the structural model is evaluated by observing the estimated path coefficients, T-statistics, and P-values resulting from the bootstrapping procedure. Referring to the decision-making rules of Hair et al. (2022), a hypothesis is declared supported if the P-value is less than the specified significance level (Ω = 0.05) and the T-statistic exceeds the critical value of 1.96 (for two-tailed testing). The following is a description of each test path:

*Hypothesis 1 (H1): The Influence of Corporate Policies & Culture on QMIS*

The empirical test results show that Corporate Policy & Culture has a positive and significant influence on the adoption of Quality Management Information System (QMIS). This is evidenced by the path coefficient (O) value of 0.495, T-Statistics of 4.744 (> 1.96), and P-Values of 0.000 (< 0.05). This finding statistically confirms H1, which means that the stronger and more supportive the strong normative policies and quality culture embedded in an organization, the higher the level of effectiveness and success of QMIS implementation. Managerially, commitment from top management level embodied in internal regulations is proven to be an essential foundation for encouraging practitioners in the field to switch to a digital-based quality management system.

From the perspective of Quality Management (QMS) practitioners, the ability to select, implement, and utilize the appropriate Information Systems (IS) for tasks and responsibilities is crucial. Companies that achieve world-class quality demonstrate high levels of informatization and automation, often through Quality Management Information Systems (QIMS). These companies are characterized by a strong organizational culture, where management encourages quality initiatives, reduces rigid hierarchical cultures, and emphasizes quality efforts at both the individual and the organization, supporting long-term development (Li et al., 2025). Organizational culture directly influences the implementation and success of a QMS, with certain cultural profiles favoring better results than others (Willar et al., 2016; Patyal & Koilakuntla, 2018). Hierarchical and mechanistic structures can hinder the success of TQM, while organic structures with strong, quality-oriented cultures actually support its success (Rad, 2006). On the other hand, successful implementation through mimetic and normative factors will also not occur without the encouragement of coercive factors in the form of government regulations and policies (Setyawan et al., 2023). Industrial transformation itself is based on government initiatives to utilize digital systems such as QMIS and BIM (Wang & Yu, 2024).

*Hypothesis 2 (H2): The effect of BIM on QMIS*

Testing on the second path confirmed the existence of a strong causality between Building Information Modeling (BIM) and QMIS. Based on the table, the path coefficient value was obtained at 0.458 with a T-Statistics of 4.265 (> 1.96) and a P-value of 0.000 (< 0.05), so that H2 was declared supported. The positive direction of the coefficient indicates that the maturity of BIM utilization is directly proportional to the optimization of QMIS functions. In the context of construction project operations, BIM technology plays a crucial role in supplying precise geometric data and structural information, which are then integrated and further managed by QMIS to ensure comprehensive quality standards.

One of the key impacts of BIM is the digitization and centralization of quality documentation. BIM facilitates the development of a digitized construction quality document management system (CQDMS). The QMS-BIM framework, for example, integrates the QMS with BIM to centralize and digitize the CQDMS, standardizing the construction QMS for consistency and security. This effectively addresses the challenges associated with conventional, complex, inefficient, and manual CQDMSs, such as improper documentation, cumbersome handling of non-conformance reports (NCRs), and inadequate recordkeeping (Ghosh & Kamkar, 2025).

BIM enables more proactive quality management, automatically identifying issues and deviations from quality standards, triggering rapid corrective action, and minimizing defects. Furthermore, BIM integration within QMIS improves communication, bridging gaps in traditional systems. This rich data integration makes BIM a key pillar for improving design quality, reducing errors, and optimizing collaboration in project management (Chen & Luo, 2014) Comprehensive documentation ensures accountability and facilitates audits, providing insights for future projects. BIM even supports government engineering quality control, enabling digital tracking of project progress and quality status (Lin et al., 2016).

*Hypothesis 3 (H3): The Effect of QMIS on Defect Management*

Analysis of the third hypothesis proves that QMIS has a positive and highly significant impact on Defect Management performance. The bootstrapping results recorded a fairly high path coefficient estimate of 0.619, supported by a T-Statistics value of 4.790 (> 1.96) and P-Values of 0.000 (< 0.05). The decision to accept H3 provides important insights that the data centralization and traceability capabilities of the QMIS digital platform are very effective in accelerating the process of identifying, reporting, and repairing defects in the field. The availability of real-time quality information prevents documentation omissions that often occur in conventional inspection methods.

Conventional quality management practices, particularly document-based Construction Quality Document Management Systems (CQDMS), often face significant challenges in defect management. These challenges include a lack of operational efficiency in the quality inspection (QI) process, ineffective defect management during the construction phase, difficulty tracking defect history using traditional 2D drawings, incomplete defect records, and a lack of effective platforms to assist quality managers on the jobsite. Furthermore, these conventional systems are riddled with complexity, inadequate documentation, complicated handling of nonconformity reports, and inadequate recordkeeping, all of which increase the risk of defects (Ghosh & Kamkar, 2025; Lin et al., 2016).

*Hypothesis 4 (H4): The Effect of Defect Management on Efficiency & Effectiveness*

In contrast to the other path constellations, testing the fourth hypothesis failed to demonstrate sufficient statistical evidence. The relationship between Defect Management and Efficiency & Effectiveness only yielded a very weak path coefficient (O = 0.061), with a T-Statistics value of 0.409 (<1.96) and P-Values of 0.683 (far above the critical limit of 0.05). Therefore, H4 was empirically rejected. This finding indicates that tactical-reactive defect management activities—even when carried out well—do not have direct leverage to improve the overall efficiency of the QA process. Defect management is positioned more as a means of fulfilling operational obligations (compliance), rather than as a primary parameter driving management efficiency, unless integrated with a more holistic information system.

Various literature indicates that the direct impact of building defects does not drastically hamper the efficiency and effectiveness of overall building management, provided that comprehensive mitigation measures are consistently implemented. While both structural and non-structural defects can inherently disrupt cost management and operational resource allocation, a thorough understanding of their root causes—such as poor workmanship and inadequate technical planning—is crucial to prevent escalation of problems and optimize the effectiveness of the building management process itself (Karunasena et al., 2025; Ahzahar et al., 2011).

Furthermore, the integration of quality management systems plays a vital role as a proactive detection tool for evaluating and correcting defects, particularly those that have the potential to degrade energy performance. The existence of these systems has been shown to substantially reduce negative impacts on a building's functional performance, even amidst deficiencies or gaps in current standard inspection procedures (Alencastro et al., 2019).

Ultimately, implementing managerial-level strategies to address building defects directly correlates with a variety of long-term macroeconomic benefits. These include reduced maintenance cost ratios, increased efficiency in construction procedures, and guaranteed extended building lifespans. Achieving these operational governance levels will be even more robust if supported by the use of cutting-edge technology and a continued focus on environmental sustainability, both of which serve as essential pillars in refining future building management practice standards (Hauashdh et al., 2022).

*Hypothesis 5 (H5): The Effect of QMIS on Efficiency & Effectiveness*

The results of the fifth hypothesis testing place this path as the causal relationship with the strongest predictive power in the overall model. QMIS is proven to have a positive and highly significant influence on operational Efficiency & Effectiveness, indicated by the highest path coefficient value of 0.695, T-Statistics 5.045 (> 1.96), and P-Values 0.000 (< 0.05). The acceptance of H5 provides a conclusive conclusion that the digitalization of the quality management system (QMIS) is a true determinant of project efficiency. The reduction of paper bureaucracy, automation of inspection workflows, and ease of data access between stakeholders facilitated by QMIS significantly reduce the redundancy of time and resources, thus leading to a fundamental increase in the effectiveness of construction quality management.

Quality Management Information Systems (QMIS) significantly improve the effectiveness and efficiency of building management by integrating quality management and information technology. QMIS improves operational efficiency through real-time data analysis, automated processes, and enhanced communication. Digital QMS systems such as QMS-BIM have been shown to be at least 78% more effective and score at least 80% across all criteria compared to conventional methods. One of the key benefits of QMIS is improved data management and accessibility. QMIS manages various quality documents (e.g., inspection reports) in a unified and secure platform, reducing disorganized formatting issues and document access delays by up to 82.6% and managing quality documents by up to 90% efficiently. It also improves data availability and accuracy (Ghosh & Kamkar, 2025).

In terms of cost and time, QMIS generates cost savings and reduces rework. The system simplifies document retrieval by up to 82.6%, reduces cost challenges by 82% by eliminating printing costs, and provides access to incident evidence with 83.3% greater effectiveness. QMIS also improves the management of Request for Information (RFI) records, Non-Conformance Reports (NCRs), and audit procedures, promoting clarity and transparency. Furthermore, QMIS contributes to improved project quality and safety through proactive defect prevention, reducing risks and liabilities. It ensures better adherence to schedules, cost estimates, and quality standards by reducing non-conformances. QMIS also enhances collaboration among stakeholders with efficient channels for defect reporting and rapid correction (Li et al., 2025).

Based on the results of testing the five direct influence hypotheses, a synthesis can be drawn that narrows down to one main conclusion: the Quality Management Information System (QMIS) acts as the centerpiece and the most critical determinant in the quality management architecture of construction projects. Holistically, this model proves the existence of a sustainable digitalization value chain. In the input phase, QMIS adoption is proven to be unable to stand alone; it absolutely requires a driving catalyst in the form of leadership commitment manifested in Corporate Policy & Culture (H1) and a technical infrastructure foundation in the form of Building Information Modeling (H2). The integration of these two exogenous variables—the socio-managerial dimension and the technological dimension—is a mandatory prerequisite for QMIS implementation to run effectively and be calibrated to project needs.

In the output and outcome phases, the findings of this study provide very sharp theoretical and managerial insights, especially when juxtaposing the acceptance of H3 and H5 with the rejection of H4. Empirically, QMIS has proven to be very reliable in boosting the performance of defect governance (Defect Management) and simultaneously increasing project Efficiency & Effectiveness. However, the anomaly in the failure of the relationship between Defect Management and Efficiency & Effectiveness (H4) confirms that quality improvement activities in the field are essentially reactive corrective actions. No matter how well the project team fixes a defect, the activity still absorbs additional costs, time, and energy, so it does not have the leverage to create "efficiency".

*Mediation Hypothesis Test*

Table 9
Mediation Hypothesis

| Hypothesis | Path | Path Coefficient (O) | T-Statistics | P-Values | Decision |
|---|---|---|---|---|---|
| **H6** | Company Policies & Culture→QMIS→Defect Management | 0.307 | 3,078 | 0.002 | Accepted / Supported |
| **H7** | BIM→QMIS→Defect Management | 0.284 | 3,586 | 0,000 | Accepted / Supported |
| **H8** | QMIS→Defect Management→Efficiency & Effectiveness | 0.038 | 0.407 | 0.684 | **Rejected / Not Supported** |

Source: Author's Processed Data (2026)

Mediation hypothesis testing aims to evaluate the role of intermediary variables in bridging the relationship between the independent and dependent variables. A mediation hypothesis is declared supported if the P-value is below the 0.05 significance level and the T-statistic exceeds the critical threshold for testing. The following is a detailed description of each mediation pathway (H6 to H8):

*Hypothesis 6 (H6): The influence of Corporate Policy & Culture on Defect Management is mediated by QMIS*
The empirical test results prove that the Quality Management Information System (QMIS) is able to mediate the influence between Corporate Policy & Culture on Defect Management positively and significantly. This is indicated by the path coefficient value of 0.307 with a T-statistic of 3.078 and a P-value of 0.002 (<0.05). The decision to

accept H6 indicates that quality regulations and organizational culture cannot work independently to reduce the number of construction defects in the field. The vision and policies of top management can only be realized into measurable and tactical defect control actions if the company provides a digital platform (QMIS) as its main work tool. In other words, QMIS acts as a translator from managerial policies into field operational instruments.

*Hypothesis 7 (H7): The effect of BIM on Defect Management is mediated by QMIS*
Testing of the seventh hypothesis confirms the existence of significant mediation of QMIS on the relationship between Building Information Modeling (BIM) and Defect Management. Based on data extraction, a path coefficient value of 0.284 was obtained with a T-Statistic of 3.586 and P-Values of 0.000 (<0.05), thus H7 is declared supported. This finding provides technical insight that 3D modeling and building information data from BIM—although very sophisticated—requires a quality management system to manage its repair workflow. QMIS functions as a platform to capture, distribute, and monitor the follow-up of non-conformity findings that may have been visualized by BIM, so that the defect resolution process becomes more structured and transparent.

*Hypothesis 8 (H8): The effect of QMIS on Efficiency & Effectiveness is mediated by Defect Management*
In contrast to the success of the QMIS mediation function, the Defect Management variable has proven to fail to carry out its mediation role. The indirect relationship from QMIS to Efficiency & Effectiveness through Defect Management produces a very marginal coefficient (0.038) with a T-Statistic of 0.407 and P-Values of 0.684 (> 0.05). Therefore, H8 is empirically rejected. This rejection is very logical from an engineering perspective; defect management activities, no matter how well managed using QMIS, are essentially a process of handling "failures" or rework. Rework always consumes additional costs and work time. Therefore, the defect management route will never lead to "efficiency." QMIS creates efficiency directly (as proven in the previous direct effect test) through automation and prevention, not through repairing defects that have already occurred.

*RQ 2 Results*
The analysis of Research Question 2 presents empirical evidence regarding the integration between the variables of Quality Information Management System (QMIS), Organizational Policy and Culture, defect management, BIM and technology, and QA Process Efficiency and Effectiveness using the Structural Equation Modeling-Partial Least Squares (SEM-PLS) approach. A total of 72 indicators has obtained approval based on expert consensus and are used as research instruments for RQ 2. This shows that, substantially, the indicators used have been considered relevant, representative, and appropriate to explain the research construct.

The results of the measurement model analysis using SEM-PLS indicate that all indicators have an adequate level of individual reliability. The outer loading values of all indicators are above the minimum threshold, indicating that each measurement item is capable of robustly representing its latent construct. The absence of indicators requiring elimination indicates that the research instrument design has a stable measurement structure. This finding is further supported by the results of convergent validity testing through the Average Variance Extracted (AVE) value, where all constructs have exceeded the required minimum threshold. Thus, each construct is able to adequately explain a proportion of the variance in its indicator.

In terms of construct reliability, Cronbach's Alpha and Composite Reliability values demonstrate excellent internal consistency across all research variables. This indicates that the indicators within each construct have a strong relationship and consistently measure the same concept. Meanwhile, the results of the discriminant validity test using the HTMT and Fornell-Larcker criteria indicate that each construct in the model has clear conceptual differences. With the fulfillment of convergent validity, construct reliability, and discriminant validity, the measurement model can be declared valid and reliable to proceed to the structural model testing stage.

At the structural model evaluation stage, the value R-squared. The results show that the model has a fairly strong explanatory power. The defect management and QMIS variables obtained R-Square values in the substantial category, while the QA process Efficiency and Effectiveness variables were in the moderate category. This indicates that the relationship between variables in the model is able to explain the variation of endogenous constructs quite well. Specifically, this model is able to explain that the success of defect management and QMIS optimization is greatly influenced by a combination of policy factors, organizational culture, and BIM technology support. Meanwhile, the efficiency and effectiveness of the QA process can be explained moderately by the quality information system mechanism and defect governance contained in the model.

The results of direct hypothesis testing show that QMIS occupies a central position in the research model. Organizational policies and culture are proven to have a positive and significant influence on QMIS, which means that the successful implementation of a quality information system is highly dependent on internal regulatory support, management commitment, organizational discipline, and a strong quality culture. Furthermore, BIM is also proven to have a positive and significant influence on QMIS. These findings confirm that model-based technology integration can strengthen the function of QMIS by providing spatial information, visualization, element traceability, cross-platform coordination, and project data consistency.

Furthermore, QMIS has been proven to have a positive and significant impact on defect management. This means that the better the implementation of QMIS, the more effective the process of identifying, tracking, managing, documenting, and closing defects. QMIS provides a mechanism for centralizing data, audit trails, digital reporting, assigning PICs, monitoring status, and more systematically documenting findings. Thus, QMIS can reduce the weaknesses of conventional defect management practices, which generally still face obstacles such as data fragmentation, incomplete documentation, weak tracking processes, and delays in corrective follow-up.

Another important finding is that QMIS also has a positive and significant impact on the efficiency and effectiveness of the QA process. This path indicates that the efficiency and effectiveness of the QA process are largely driven by the system's ability to accelerate information flows, reduce duplication of input, simplify data access, standardize reporting formats, and automate quality monitoring and evaluation processes. In other words, QMIS functions not only as an administrative documentation tool, but also as a managerial instrument capable of improving the speed, accuracy, coordination, and transparency of the construction quality assurance process.

Conversely, the direct relationship between defect management and the efficiency and effectiveness of the QA process was not proven to be significant. This finding indicates that defect management activities, although very important in maintaining the quality of work results, do not necessarily directly create efficiency and effectiveness. In practice, defect management is a corrective activity carried out after defects occur. Therefore, this process still requires additional time, costs, labor, coordination, and verification. Good defect repair can ensure the quality of work returns to standards, but it does not necessarily mean the QA process is more efficient and effective. Efficiency is actually stronger when the system is able to prevent defects, accelerate early detection, and provide accurate information before problems develop into rework.

The results of the mediation test also strengthen the position of QMIS as a key variable. QMIS has been proven to mediate the influence of organizational policies and culture on defect management. This indicates that organizational policies and quality culture cannot function optimally if they are not translated into a structured digital work system. QMIS becomes a medium that transforms managerial commitment into operational mechanisms that can be implemented in the field, for example, through reporting flows, approval mechanisms, document control, role allocation, and defect follow-up monitoring.

QMIS has also been shown to mediate the influence of BIM on defect management. This finding confirms that BIM is not enough to be positioned only as a visualization tool or technical modeling, but needs to be integrated with a quality information system in order to have a real impact on defect management. Through QMIS, information from BIM can be translated into more operational work processes, such as recording findings on model elements, determining the location of defects precisely, associating defects with activities or work zones, monitoring repair status, and storing data for audit needs and project learning.

However, defect management was not proven to mediate the effect of QMIS on QA efficiency and effectiveness. This makes it clear that the contribution of QMIS to QA efficiency and effectiveness does not occur primarily through the process of handling defects after they arise, but rather through the system's direct function in digitizing and integrating the QA process. Stronger efficiency is generated by prevention mechanisms, automation, information centralization, increased data accessibility, reduced administrative redundancy, and accelerated coordination between parties. Thus, QMIS plays a role not only as a supporter of the corrective process but also as a foundation for transforming the QA process from a reactive pattern to a data-driven, preventive pattern.

Overall, the results of the RQ 2 analysis confirm that improving the efficiency and effectiveness of QA processes in construction projects cannot rely solely on conventional defect management practices. Defect management remains necessary as a quality control mechanism, but its role will be more optimal when supported by an integrated quality information system. In this context, a QMIS serves as the central hub connecting policy, organizational culture, BIM technology, and defect management into a more systematic digital framework.

Thus, it can be concluded that the QMIS-BIM integration model developed in this study has a strong empirical basis. Organizational policies and culture provide the managerial foundation, BIM provides the technological and visual-spatial foundation, while QMIS acts as an information management system that translates both into a more measurable QA process. This integration enables the defect management process to be carried out in a more documented, traceable, coordinated, and information-based manner. Ultimately, increased QA efficiency and effectiveness are more likely to be achieved through a digital system that is preventative, integrated, and real-time, rather than through a corrective process that only focuses on resolving defects after they occur.

The results of RQ 1 provide an explanation of various problems frequently encountered in the existing defect management process and directly impact field and company operations. By considering the impact mapping contributed between variables in RQ 2, development solutions are formulated not only as technical responses to each problem, but also as systemic strategies that follow empirically proven causal relationships. The development solutions are directed at strengthening the Quality Information Management System (QMIS) where QMIS is positioned as the center of integration between quality policies, BIM technology, and defect management processes in the field.

Table 10
Mapping and Grouping of Issues

| No | Key Issue Groups | Issues included |
|---|---|---|
| 1. | *Governance* and role differentiation | Ambiguity of responsibility, weak access control, low concern to accommodate the process. |
| 2. | Information management and traceability | Suboptimal information flow between users, data duplication, information inconsistency, information fragmentation, data is difficult to trace and utilize. |
| 3. | Workflow coordination and integration | Failure of communication and coordination between teams, workflow obstacles, process insynchronization, delays in handling processes. |
| 4. | Process efficiency and workload distribution | Job redundancy, slow and costly reporting processes, low time efficiency, and large administrative workloads. |
| 5. | *Monitoring,* cost evaluation and control | Difficulty in evaluation, low and undocumented closing rates, inability or imprecision of cost estimates. |
| 6. | Preventive measures and continuous improvement | The absence of continuous improvement, late prevention, high potential for recurrence of similar defects in the same item/location. |
| 7. | System adaptability to field dynamics | Low relevance of the system to field dynamics, workflow obstacles, low concern for accommodating the process. |
| 8. | *User readiness* and technology adoption | Lack of user knowledge of the system, low level of technology adoption, the system as an administrative workload and not as a solution instrument. |

Source: Author's Processed Data (2026)

Table 11
QMIS-BIM Integration Development Solutions

<table>
<tr><th>No</th><th>Issue</th><th>Development Solutions</th></tr>
<tr><td>1.</td><td>Governance and role differentiation</td><td>Strengthening the distribution of responsibilities oriented towards QMIS-BIM integration through the following role division:<br>Table 11.1 Development of Role and Responsibility Distribution
<table>
<tr><th>Role</th><th>Main Responsibilities</th></tr>
<tr><td>Examiner</td><td>Finding and reporting indications of work defects</td></tr>
<tr><td>Project QA/QC/QHSE functions</td><td>Verify reports, classify defect findings, check repair results, and close defects.</td></tr>
<tr><td>Project Team</td><td>Provide additional project supporting data where necessary, assist with impact analysis, and implementation coordination.</td></tr>
<tr><td>BIM project operator</td><td>Linking defect findings to models, modeling corrective actions, estimating model-based costs, simulating repair schedules, and updating issue status in BIM/CDE.</td></tr>
<tr><td>Field PIC</td><td>Carry out repairs in the field according to the established</td></tr>
</table></td></tr>
</table>

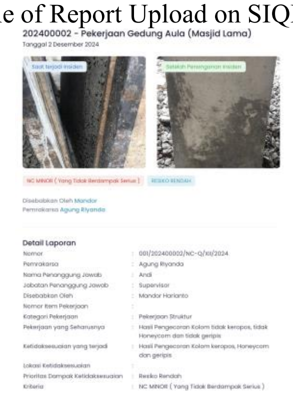
| | |
|---|---|
| | plan. |
| Project Manager | Approve follow-up, assign Field PIC, approve proposed repair time and costs |
| QHSE Manager Head Office | Controlling, evaluating, and validating quality at the managerial level |
| Head Office Operations Department | Provide approval for reports, align processes and outcomes according to organizational governance |

Adjustments to each role must be socialized and integrated into the SOP/governance of each function to ensure full understanding and commitment to the responsibilities of each role. In special cases, for example, in projects with consortia or design and build projects involving planners, dashboard access rights should also be considered for distribution to external initiators of the company (with restrictions) to clarify the distribution of responsibilities and strengthen the commitment to quality management.

2. Information management and traceability

The following is an example of uploading a report regarding a defect found on an existing dashboard.

Figure 11.1 Example of Report Upload on SIQHA Dashboard Page




By utilizing the data repository managed by the BIM function (issue log, RFI log, and daily log) via a plugin connected to the dashboard page, specifically in the Defect Identification Phase, reporters can mark defect locations directly in the BIM model or the BIM viewer connected to the QMIS dashboard report creation page. This is possible based on the model developed by Wang & Yu (2024), through the use of a lightweight platform, allowing BIM models to be easily accessed via the web or smartphone. By doing so, the data reference presentation will enhance understanding of the actual location of the defect, the affected elements, and the technical context of the defect through the available spatial representation. In a cyclical manner, its utilization can be formulated as follows:

Table 11.2 Example of Proposed BIM Utilization in the Defect Phase

| **Stage** | **Utilization of BIM** |
|---|---|
| Defect Identification Phase | - The reporter marks the defect location on the BIM model and uploads evidence. |
| | - The system associates defects with elements, discipline zones, and technical documents. |
| Defect Tracking Phase | - QA/QC compares reports with models, drawings, specifications, and RFIs. Tracks the presence of other defects by utilizing BIM models.<br>- Chronological search via timestamps on issue logs, RFI logs, and daily logs |
| Defect Management Phase | - BIM operator provides visualization, quantity take-off, cost estimation, and repair schedule simulation.<br>- Referring to validated instructions, models and references through QMIS-BIM integration, field PICs carry out repairs |

<table>
<tr><td></td><td></td><td>
<table>
<tr><td>Defect Closure Phase</td><td>- Verify fixes and update status via model.<br>- Cross-disciplinary status synchronization that is socialized across all projects and operational departments.</td></tr>
<tr><td>Defect Documentation Phase</td><td>- Historical data is stored with timestamps for later analysis and evaluation.</td></tr>
</table>

With the connection between QMIS reports and BIM model elements, information about the defect cycle is no longer fragmented, but is structured into a single, traceable data chain.

Figure 11.2 Example of Information in BIM Element 1

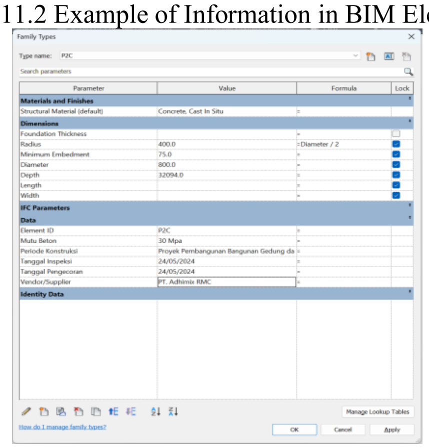
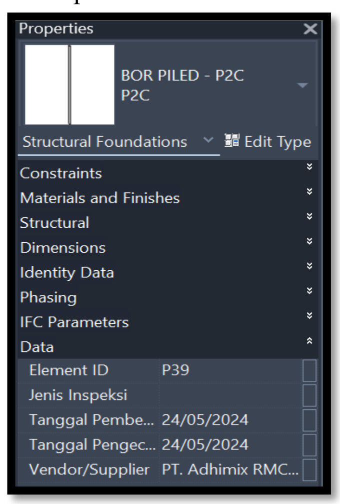
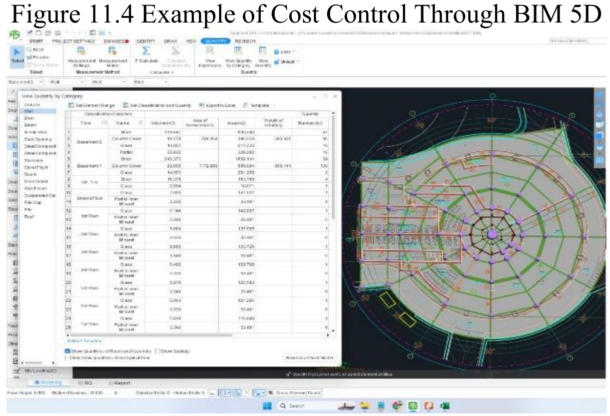



Figure 11.3 Example of Information in BIM Element 2




The following are links to information attached to each BIM element. This information extends beyond technical specifications to include non-geometric data such as job status, inspection dates, change history, element identity, and even vendor and supplier information.
</td></tr>
<tr><td>3.</td><td>Workflow coordination and integration</td><td>Reflecting on the Braglia design model (2014) and Jabbar (2022), The following is a draft of the technical coordination and warning flow mechanism in QMIS-BIM:<br>Control tower as an early warning system:<br>It functions as a monitoring instrument for work status by comparing it to the proposed deadline plans. The control tower can be divided into two accesses according to the hierarchy of positions:<br>- Project control tower with QHSE as the organizer: to monitor and ensure that the field (site) completes defect work according to the established plan.</td></tr>
</table>

<table>
<tr><td></td><td></td><td>- Head office control tower with operational QHSE department: to ensure the project carries out defect management according to its workflow, and for all administrative requirements to be met.<br>Setting response time limits (SLAs):<br>The control tower sends alerts requiring users to adhere to specific deadlines at each stage of defect management. This is intended to support decision-making based on prioritization of tasks according to their level of urgency. The workflow is completed in a hierarchical manner, ensuring alerts are routed to the appropriate responsible person.</td></tr>
<tr><td>4.</td><td>Process efficiency and workload distribution</td><td>Based on the available literature, automation through QMIS-BIM integration fundamentally transforms existing processes into streamlined, digital processes. This directly improves process efficiency, reduces physical fatigue, and optimizes personnel work distribution through:<br>1. Eliminate the burden of repetitive manual work that previously relied heavily on human labor and error-prone paper-based documents.<br>2. Process acceleration and massive time savings by eliminating delays caused by manual bureaucracy. Quality control can be done directly in the field using a device without having to return to the office to retype. Digital approvals and verification replace verbal communication with automated channels.</td></tr>
<tr><td>5.</td><td>Monitoring,cost evaluation and control</td><td>BIM 5D is equipped with the capability to add a cost dimension to each model element, linking it to volume, quantity, unit price, estimated cost, and cost changes due to changes. In the existing dashboard, identified defect reports were not linked to cost traceability, so the estimated costs presented were only textual descriptions. Through the utilization of BIM 5D, analytical information such as the following can be displayed:
<table>
<tr><th>Evaluation Indicators</th><th>Function</th></tr>
<tr><td>Total cost of rework/repair</td><td>Measuring the financial impact of a defect finding</td></tr>
<tr><td>Defect cost per zone</td><td>Identifying the work areas with the greatest losses with the support of models as a reference</td></tr>
<tr><td>Defect cost per discipline</td><td>Know which jobs most frequently incur correction costs.</td></tr>
<tr><td>Actual vs estimated costs</td><td>Evaluate the accuracy of cost predictions.</td></tr>
</table>
Figure 11.4 Example of Cost Control Through BIM 5D

Integration of 5D BIM into QMIS can link reports with model elements, work quantities, cost codes, BoQ, estimated repair costs, and actual costs incurred.</td></tr>
<tr><td>6.</td><td>Preventive measures and continuous improvement</td><td>A graphical representation linking BIM components to their defect attributes allows users to filter, search, and access defect information in layers based on problem type and similar attributes.(YC Lin et al., 2016)This mechanism uses a method of grouping items based on data attribute information/links. QMIS-BIM integration supports the system to extract "structural type" and "material type" information from BIM families to group areas that have</td></tr>
</table>

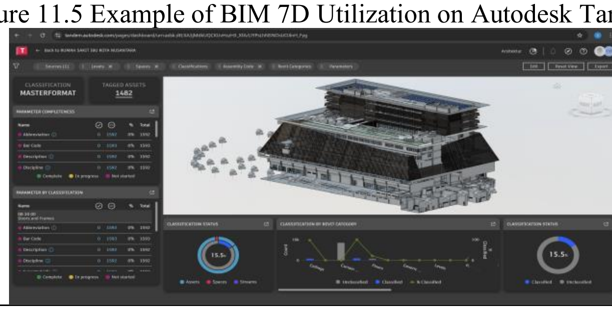
the potential to have similar defects and narrow and direct further inspections to Regions of Interest only. The following groupings of elements can be considered in QMIS-BIM integration:

Table 11.3 Example of Item Grouping Through BIM

| Basic Grouping | Usage Examples |
|---|---|
| Asset categories | Door category, AC category, electrical panel category |
| Building system categories | HVAC system, plumbing system, and fire protection system |
| Location | Per floor, per zone, per room |
| Supplier | Products from specific vendors |
| Operational Risk | Critical and non-critical assets |
| History | Assets with previous defects, assets with recurring defects |
| Warranty period | Assets that are still in the warranty period |

Another solution offered is utilizing asset tagging in BIM 7D and Autodesk Tandem, which can be positioned as a follow-up solution to BIM-QMIS integration by providing an operational asset database. Asset tagging involves assigning operational identities and attributes to BIM model elements so they can be managed, filtered, tracked, and evaluated throughout the building's lifecycle. This concept is supported through asset classification, parameter sets, and facility templates in the building's digital twin.

Figure 11.5 Example of BIM 7D Utilization on Autodesk Tandem



7. System adaptability to field dynamics

System adaptability to field dynamics is one of the determining factors for system adoption. The QMIS-BIM development solution is aimed at establishing a standardized yet flexible reporting system. Standardization ensures consistent defect management processes within the workflow, and flexibility ensures the system remains relevant and adaptable regardless of the project characteristics. The relationship can be explained as follows:

Table 11.4 System Adaptability Features Table

| | |
|---|---|
| Data standardization | Ensure consistency, traceability, and uniformity of defect information on each project |
| Reporting flexibility | Allows information to be presented according to user needs. |
| System flexibility | Allows the system to configure its interface to meet user needs. |

Standardization is achieved by establishing standard core data for each report, which standardizes the final output. This structure ensures that each report has a consistent and traceable information format. This aspect can be achieved through:

- POP (Product, organization, process) based templates that are tailored to national, industry, and local standard criteria (Chen & Luo, 2014)
- Automation of defect management flow via hierarchical flow dictation that ensures tasks are performed in a strict sequence (Ghosh & Karmakar, 2025).

| | | |
|---|---|---|
| | | Report flexibility refers to the ability to customize report output for various needs by relying on automatic retrieval, sorting, and filtering based on the system's data repository. Users can configure and customize data so that each presentation has its own visual format. This allows each user to tailor reports to their individual needs (audits, weekly/monthly reports). (Van Besouw & Bond-Barnard, 2021) For example, BIM operators can display reports based on model elements linked by BIM version defect information, PICs can monitor repair deadlines, while PMs and QHSEs can quickly obtain a summary of defect management progress, risks, costs, and performance.<br><br>System flexibility aims to improve user experience, smooth navigation, and provide visibility into the performance metrics they most want to monitor. This can be achieved through interface personalization, for example. This feature allows users to easily customize the dashboard appearance and application layout to suit their preferences. (Sihombing, 2024). In his research, Wang & Yu (2024) produce a quality control system that carries the concept of role differentiated management and personalized page experience, which can provide an exclusive work interface for each user according to their respective portion of responsibility and job hierarchy. |
| 8. | *User readiness* and technology adoption | The transition to digital-based defect management through QMIS-BIM integration is not just a technological change, but also a transformation of the organization and work culture. Therefore, system evaluation, regular training, and role socialization are vital to ensure consistent adoption and strong commitment.<br><br>Without socialization to build cultural commitment, training to ensure operational proficiency, and evaluation to maintain system relevance, investments in QMIS-BIM technology will result in underutilized applications due to user resistance. These three elements ensure that defect management standards are implemented and consistent across all projects. |

## 4 Conclusion

Based on the research results, it can be concluded that developing a BIM-integrated QMIS is a strategic need to support the quality management transformation process, especially in the QA aspect. The urgency to respond to system optimization opportunities is based on an empirical basis that considers the operational needs of the system users themselves. In the context of this research, it is considered that reflecting on several studies that describe the conditions of system implementation with all its sophistication, it cannot be denied that technological transformation is essential to maintain the competitiveness of construction service providers in Indonesia. High-complexity projects, which are the market segment of PT X, indirectly act as a catalyst for coercive drivers for companies to adopt digital innovation to support their operations. However, full digital transformation is impossible if it is not supported by the culture and maturity of organizational quality. Top management commitment to digital transformation also needs to be instilled as early as possible, starting from system design, system implementation, and continuous evaluation that ensures the system remains relevant, fulfills its role according to its specialization and capabilities, so that it can be operated optimally as it should. The costs allocated by a company to investments in various IT/systems/platforms must be balanced with the substantial benefits derived from those IT/systems/platforms. Company resources, both tangible and intangible, must be utilized to the maximum extent possible in accordance with their intended use to maximize quality achievement. In the context of the investment costs that companies have poured into various digital-based construction frameworks, the determining factor for this success depends on interoperability and cross-platform integration.

Employee resistance to technology can be minimized by increasing awareness of the benefits that the system itself can contribute. Employee motivation and commitment should also be recognized through the provision of facilities and resources such as regular training, device provision, and certification, which are expected to gradually shift the stigma surrounding the complexity of digital transformation. Ultimately, operational excellence depends not only on the existence of the system itself but also on the utilization of appropriate strategies oriented towards clear goals.

Future research could examine and explore similar aspects not only within a single company but also broaden the analysis's focus to a national scale. This would strengthen the regulatory (government) basis for dictating project implementation, supported by targeted and measurable mechanisms through digital implementation.

*Conflict of interest statement*

The authors declared that they have no competing interests.

*Statement of authorship*

The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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