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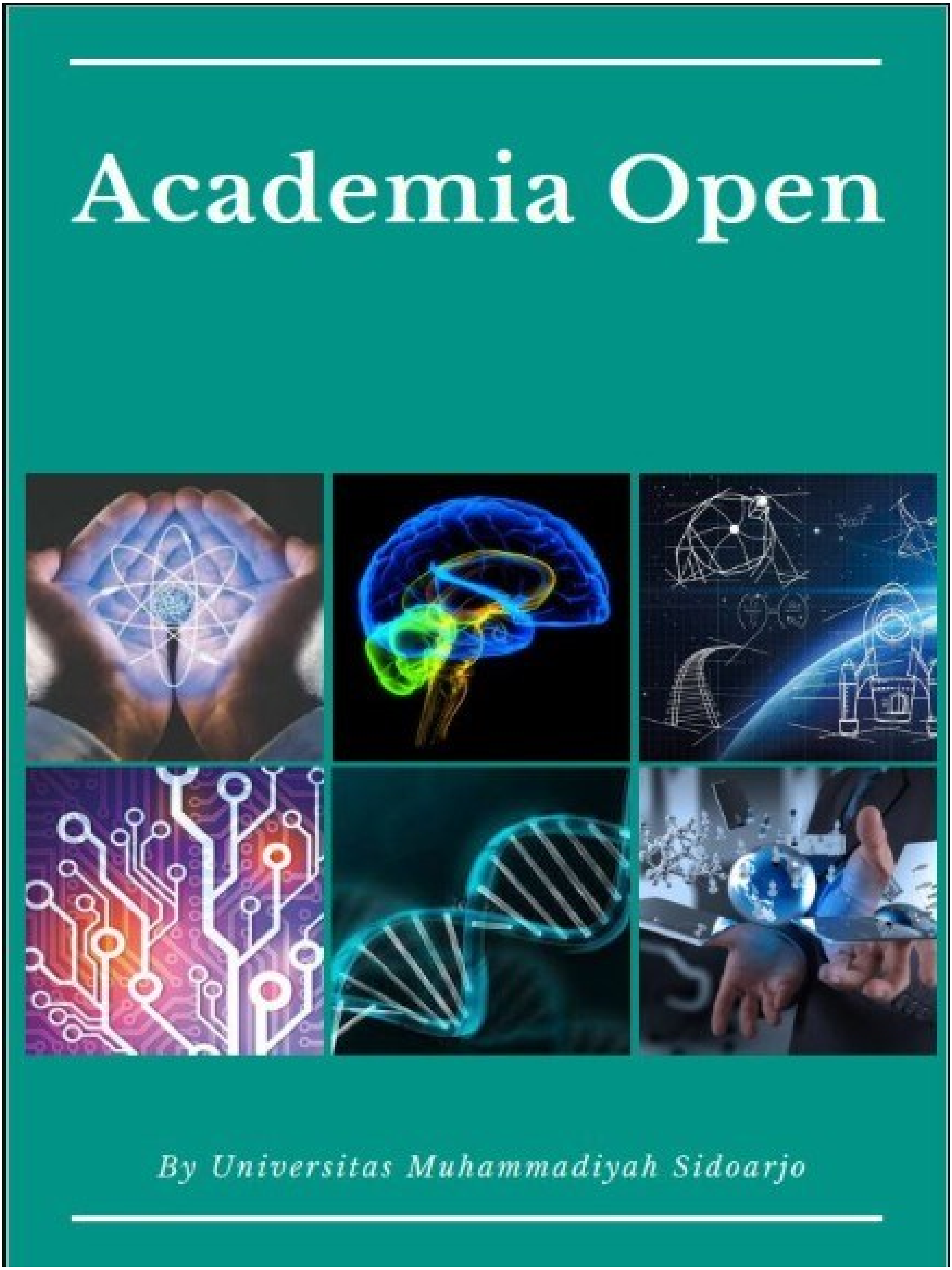

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Readiness for the Implementation of Building Information Modeling (BIM) in Controlling Construction Costs for Public Works Projects During a Crisis in Timor-Leste

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Abstract

This study examines the readiness for implementing Building Information Modeling (BIM) in controlling construction costs for public works projects during a crisis in Timor-Leste. **General Background:** Public construction projects are complex and frequently face cost overruns and delays, particularly under crisis conditions such as economic instability and supply chain disruptions. **Specific Background:** BIM, particularly 5D BIM, offers integrated digital solutions for improving cost estimation, information transparency, and project coordination. **Knowledge Gap:** Limited research addresses BIM implementation readiness by considering structural, technical, and institutional dimensions simultaneously, especially in developing countries during crises. **Aims:** This study aims to analyze BIM implementation readiness, identify key challenges, and examine its role in construction cost control during crisis situations. **Results:** Findings indicate that BIM readiness remains at an early stage, characterized by low stakeholder understanding, limited human resources, inadequate infrastructure, and lack of policy support, while project practices are still dominated by fragmented and conventional systems. **Novelty:** The study introduces a systemic readiness perspective integrating structural, technical, and institutional factors within a crisis context. **Implications:** The results highlight the need for a comprehensive approach involving human resource development, digital infrastructure strengthening, and regulatory support to facilitate BIM adoption and improve cost control responsiveness in public construction projects.

Highlights:

- Early-stage adoption is marked by limited expertise, infrastructure constraints, and minimal institutional backing.
- Project management practices remain fragmented with reliance on manual and non-integrated systems.
- Systemic alignment of structural, technical, and regulatory elements is required for digital transition.

Keywords: Building Information Modeling (BIM), Cost Control, Public Construction Projects

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Introduction

Public construction projects play a strategic role in driving economic growth, providing public services, and improving the quality of life for the community. However, the high complexity of these projects and the large investment involved make cost and schedule control major challenges in project management. Various studies indicate that cost overruns and delays are common occurrences, particularly in developing countries. More than 30% of construction projects experience significant cost deviations due to inadequate planning, inaccurate estimates, and poor coordination among stakeholders [1], [2].

In recent years, various crises, including global economic instability, the COVID-19 pandemic, and disruptions in supply chains, have adversely affected the performance of construction projects. Variations in material prices and limitations in public budgets have become the main factors influencing the precision of cost estimations and the actual costs incurred during project implementation.[3] In addition, design changes, adjustments to the scope of work, and increased risks of claims and contract disputes further complicate project cost control. These conditions indicate that conventional, static cost control approaches are no longer sufficient, necessitating a system that is more adaptive, responsive, and based on real-time data [4].

This situation is even more complex in developing countries such as Timor-Leste, which still faces limitations in technical, institutional, and financial capacity regarding public infrastructure development. Although infrastructure development is a national priority in the Timor-Leste Strategic Development Plan 2011–2030, its implementation is still dominated by a conventional approach based on manual documents and two-dimensional (2D) drawings, which is prone to errors and inefficiencies [5], [6]. Strategic projects such as the Tibar Bay Port demonstrate how reliance on external resources and the impact of global crises can lead to delays and increased project costs. To address these challenges, Building Information Modeling (BIM), especially 5D BIM, has developed as an innovative solution for project cost management. BIM facilitates the integration of visual (3D), scheduling (4D), and cost (5D) models within a unified digital platform, which enhances estimation accuracy, information transparency, and the effectiveness of decision-making processes. Empirical evidence indicates that the application of BIM can increase cost efficiency by up to 25% through better resource optimization and more accurate planning.[7], [8].

Nevertheless, the adoption of BIM in developing countries still faces various obstacles, such as limited human resources, low digital literacy, inadequate technological infrastructure, and organizational resistance to change [9], [10]. 12% a construction company that understands the basics of BIM [11]. The novelty of this study lies in the integration of an analysis of Building Information Modeling (BIM) implementation readiness with the context of crisis situations in public construction projects in developing countries, specifically Timor-Leste. In contrast to previous studies that primarily emphasized the technical aspects or efficiency of BIM, this research investigates BIM readiness from a systemic perspective through a qualitative approach that combines structural, technical, and institutional dimensions. Furthermore, this study introduces a new viewpoint by considering crisis conditions as a factor that affects the effectiveness of BIM implementation in project cost management.

Although numerous studies have explored the application of Building Information Modeling (BIM) in construction projects, the majority of existing research continues to concentrate on technical elements, cost efficiency, and overall rates of technology adoption. Nevertheless, there remains a significant research gap in understanding how BIM implementation readiness is influenced by the interaction of structural, technical, and institutional factors, particularly in the context of public construction projects during a crisis. Furthermore, empirical studies examining BIM implementation in developing countries such as Timor-Leste remain very limited, particularly those linking system readiness, crisis dynamics, and cost control effectiveness. Therefore, this study aims to address this gap through a comprehensive analysis based on field data.

Method

This study employs a qualitative research design using a case study approach [12]. A qualitative approach was chosen because this study aims to gain an in-depth understanding of the phenomenon of Building Information Modeling (BIM) implementation in the cost control of public construction projects, particularly within the context of a complex and dynamic crisis. This approach enables researchers to investigate the perspectives, experiences, and actual practices of project stakeholders in a contextual and comprehensive manner. A case study method was selected because the research concentrates on a particular setting—public construction projects in Timor-Leste—thereby allowing a thorough examination of the interactions among technological, managerial, and external environmental factors. In comparison with quantitative methods, the qualitative approach is more effective in capturing social complexities and decision-making processes that cannot be quantified numerically, particularly under crisis conditions characterized by uncertainty. This is consistent with the literature, which suggests that qualitative research is highly suitable for understanding complex phenomena, social interactions, and specific contexts within organizational practices and construction projects.[13].

The data collection techniques employed in this study consisted of in-depth interviews, observations, and document analysis as part of a triangulation strategy to strengthen data validity. Semi-structured interviews were carried out with project stakeholders, including project managers, engineers, consultants, and government officials involved in public construction projects in Timor-Leste. The study focused on strategic infrastructure projects located in the Dili area and nearby regions, as this area functions as the center of national infrastructure development. The participants in this research ranged from 10 to 15 individuals and were selected through purposive sampling based on the criterion of possessing direct experience in construction project management and BIM implementation. This number was considered adequate for qualitative research

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because it had reached data saturation, a stage where the information collected became repetitive and no new insights emerged. Observations were conducted to understand BIM implementation practices and cost control directly in the field, while the documentary study involved analyzing project reports, contracts, and cost planning documents. The use of this methodological triangulation is supported by recent research emphasizing that the combination of interviews, observations, and documentation can enhance the credibility and depth of analysis in qualitative studies.

The data analysis technique applied in this study utilizes the interactive analysis model developed by Miles and Huberman, which comprises three primary stages: data reduction, data display, and conclusion drawing/verification. Data reduction includes the processes of selecting, simplifying, coding, and categorizing data obtained from interviews, observations, and documentation in order to concentrate on information relevant to the research objectives. This stage is intended to refine the analysis and systematically organize the data so that it becomes more meaningful. Subsequently, the data are presented through descriptive narratives, matrices, and relationships among categories to facilitate the identification of patterns, connections, and research findings. A systematic presentation of data enables researchers to recognize patterns and relationships more effectively. The final stage involves drawing conclusions and verification, which includes interpreting the data to answer the research questions and validating the findings through triangulation and repeated examination of the data. This model is iterative and interactive, where the analysis process occurs continuously from data collection through to the final stage of the research. This approach was chosen because it produces in-depth, systematic, and accountable analysis in complex qualitative research.

Results and Discussion

The results of the interview regarding the readiness for the implementation of Building Information Modeling (BIM) in controlling construction costs for public works projects during a crisis in Timor-Leste are presented in the following table.

Table 1. Readiness for Building Information Modeling Implementation

Code	Role	Understanding Bim	Use of Bim	Main Challenges	Perception of Benefits
R1	Project Manager	Currently	Limited	Human Resources & Costs	Tall
R2	Engineer	Low	None	Lack of training	Currently
R3	Cost Engineer	Currently	Partial	Data is not integrated	Tall
R4	BIM Specialist	Tall	Aktif	Infrastructure	Tall
R5	Consultant	Low	None	Resistance	Currently
R6	Supervisor	Low	None	Lack of understanding	Low
R7	Contractor	Currently	Limited	Software costs	Tall
R8	The Government	Low	None	Policy	Currently

The table shows variations in the level of understanding, usage, and perception of BIM among respondents. In general, only a small proportion of stakeholders have actively implemented BIM, while the majority are still at the basic understanding stage or have not used it at all. Based on the interview table, a fairly clear pattern emerges regarding the distribution of BIM implementation readiness. Stakeholders with specialized technical backgrounds, such as BIM Specialists (R4) and Cost Engineers (R3), exhibit higher levels of understanding and utilization of BIM compared to other stakeholders. In contrast, government officials (R8), supervisors (R6), and consultants (R5) generally possess lower levels of BIM knowledge and have not yet integrated BIM into their professional activities. Another notable pattern is that almost all respondents recognize the advantages of BIM in enhancing cost efficiency, despite the relatively low level of its actual implementation. Furthermore, the main obstacles identified remain consistent, including limited human resources, high technology investment costs, and insufficient policy support. This situation reflects a gap between the strong perceived benefits of BIM and the still-restricted level of implementation in practice.

This pattern suggests that BIM implementation readiness in Timor-Leste remains at an early stage of adoption. The combination of high perceived benefits and low implementation rates indicates the existence of structural and institutional barriers, rather than purely technical challenges. Limited human resource capacity and a lack of training mean that project stakeholders lack the necessary competencies to operate BIM optimally. On the other hand, the absence of government policies that systematically encourage the use of BIM also slows down the adoption of this technology. In the context of a crisis, this situation becomes even more complex because budget constraints often mean that investment in digital technology is not a top priority. Therefore, BIM implementation requires not only technical readiness but also institutional support, regulations, and adaptive strategies that account for the dynamic nature of the crisis.

Based on this context, the results of field observations regarding the readiness for BIM implementation in public construction projects in Timor-Leste are presented in the following table:

Table 2. Results of field observations regarding readiness for BIM implementation

Aspect	Field Conditions
Design system	2D Drawing (AutoCAD)
Data integration	Not integrated
Use of BIM software	Very limited
Team coordination	Manual (in-person meeting)
Cost control	Separate spreadsheet
Response to change	Slow
IT Infrastructure	Limited

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The table shows that field practices are still dominated by conventional methods, with very limited and unintegrated use of digital technology. Observations reveal a pattern where nearly all aspects of project management are still carried out manually or semi-digitally. The use of 2D drawings as the basis for planning indicates that information integration across disciplines has not yet been optimized. Additionally, cost control managed through separate spreadsheets indicates the absence of a centralized system capable of linking cost data with project design and schedules. Another pattern is the slow response to changes, particularly in crisis situations such as material delays or price fluctuations. This situation occurs because every modification must be communicated manually through meetings or through document revisions that require considerable time. The lack of adequate IT infrastructure further strengthens the reliance on conventional methods, thereby limiting the comprehensive adoption of BIM.

These findings suggest that the low readiness for BIM implementation is influenced not only by human factors but also by limitations in systems and infrastructure. Dependence on traditional methods results in fragmented information, which ultimately reduces the efficiency of cost control. Under crisis conditions, this situation becomes even more critical because projects do not possess systems capable of responding to changes rapidly and in an integrated manner. BIM, which is intended to serve as a data integration platform, has not yet been implemented optimally due to the absence of a supportive digital ecosystem. This demonstrates that digital transformation in Timor-Leste's construction sector requires a systemic approach that includes infrastructure development, enhancement of human resource capabilities, and changes in organizational culture within project management. To provide additional validation of the observational findings, an analysis of project documentation regarding BIM implementation readiness in cost control is presented below.

Tabel 3. Analysis of project documentation regarding BIM implementation

Document	Findings
Cost Estimate	Not integrated into the design
Working drawing	2D Format
Progress Report	Manual
Project contract	Does not include BIM
Statement of Changes in Expenses	Not real-time
Project Schedule	Excluding costs

The data indicates that project documents are still prepared separately and have not yet been integrated into a single BIM-based system. An analysis of the documentation reveals a pattern where all project documents remain fragmented and unconnected. The Cost Estimate (RAB) is prepared without direct integration with the design, so that any design changes do not automatically update the cost estimates. Working drawings that continue to rely on 2D formats further confirm that BIM has not yet been adopted during the planning stage. Moreover, progress reports and cost variation reports that are still prepared manually cause delays in the availability of information needed for decision-making. The absence of BIM clauses in project contracts also demonstrates that the use of this technology has not yet become a standard practice within the construction industry in Timor-Leste. This pattern indicates that the project documentation system remains conventional and has not yet facilitated integrated digital data management.

The patterns identified in the documentation reveal that readiness for BIM implementation is still constrained at both the systemic and regulatory levels. The inconsistency found in project documents reflects the absence of an information-integration-based approach to project management. During crisis conditions, this situation limits the project's capacity to conduct adaptive and real-time cost control. The lack of BIM clauses in contracts further indicates that the adoption of this technology has not yet been institutionally encouraged. Therefore, BIM implementation requires transformation not only in technical practices but also in regulatory frameworks, contract standards, and project governance systems. This highlights that BIM readiness should be understood as a form of systemic readiness that simultaneously involves technological, human, and institutional dimensions. Interview findings further suggest that readiness for the implementation of Building Information Modeling (BIM) in Timor-Leste remains limited, although it carries substantial strategic implications for improving the effectiveness of project cost control. Functionally, BIM has the potential to improve the accuracy of cost estimates, information transparency, and decision-making efficiency. However, dysfunctionally, the low adoption rate leaves projects vulnerable to cost overruns and delays, particularly in crisis situations. This is supported by various studies showing that BIM can improve cost efficiency by up to 20–25% through data integration and model-based simulation [14]–[16]. Therefore, the primary implication of these findings is the existence of a gap between the potential advantages offered by BIM and the actual conditions of its implementation, which consequently leads to less effective cost control in public construction projects in Timor-Leste. The low level of readiness for BIM implementation identified through the interviews is influenced by a complex interaction of structural, technical, and institutional factors. From a structural perspective, limited human resource capacity and inadequate digital literacy constitute major obstacles to the adoption of BIM technology.

Technically, high upfront investment costs and limited technological infrastructure also slow down implementation. Furthermore, the lack of regulations and policies promoting the use of BIM reinforces organizational resistance to change. Studies indicate that BIM adoption in developing countries is significantly influenced by institutional readiness, government support, and human resource capacity [17]–[19]. Therefore, the low level of BIM readiness is not merely a technical issue, but a reflection of a system structure that does not yet support digital transformation in the construction sector.

The observation results reveal the continued dominance of conventional methods in construction project practices, which directly affects the effectiveness of cost control. From a functional perspective, the use of traditional methods still enables projects to operate; however, dysfunctionally, these approaches lead to fragmented information, delays in communication, and slower responses to changes. Under crisis conditions, such circumstances heighten the risk of discrepancies between estimated costs and actual project expenditures. The literature indicates that BIM-based systems can improve data integration and accelerate real-time responses to project changes [20]–[22]. Therefore, the main implication of the findings

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is that reliance on conventional methods is a major obstacle to improving the efficiency and resilience of construction projects in the face of crisis dynamics.

The prevalence of conventional methods in the observational findings is due to a system structure that does not yet support the digitization of construction processes. Fundamentally, project organizations still operate within a traditional work paradigm that relies on separate documents and manual communication. Limitations in technological infrastructure and a lack of investment in digital systems reinforce this situation. Additionally, an organizational culture that tends to resist change is also a key factor hindering the adoption of BIM. Studies indicate that digital transformation in construction requires a shift in organizational culture, enhanced technological capabilities, and the integration of information systems [23]–[25]. Therefore, the observed pattern is not solely caused by technical limitations, but rather by organizational structures and work systems that have not yet adapted to the advancement of digital technology.

An analysis of the documentation shows that the project management system remains fragmented, which carries significant implications for cost control. Functionally, project documents can still serve as a basis for implementation; however, the lack of integration among these documents results in low data accuracy and delays in the decision-making process. In crisis situations, this exacerbates cost uncertainty because changes cannot be monitored in real time. Studies indicate that BIM-based document integration can enhance transparency, data accuracy, and the effectiveness of project cost management [26], [27]. Therefore, the main implication of these findings is the need to transform the project documentation system toward BIM-based digital integration to improve cost control performance.

The lack of consistency in project documentation stems from the absence of standards and regulations governing the use of BIM in public construction projects. Structurally, contract systems and administrative procedures are still designed for conventional methods, and thus do not support digital data integration. Additionally, a lack of awareness regarding the importance of integrated information management also acts as a barrier. Studies show that the success of BIM implementation is heavily influenced by the existence of national standards, government regulations, and a clear framework for project information management [28], [29]. Thus, the issue of documentation is not merely technical in nature, but is also linked to regulatory structures and project governance that do not yet fully support digitization.

Based on the results of interviews, observations, and document analysis, this study developed a conceptual model of Building Information Modeling (BIM) implementation readiness for construction project cost control during a crisis. This model illustrates that readiness for BIM implementation is not determined exclusively by technical factors, but rather by the interaction of three primary dimensions: structural, technical, and institutional. From a structural perspective, BIM readiness is affected by the capacity of human resources, levels of digital literacy, and the organizational culture related to the adoption of new technologies. Technically, readiness depends on the availability of technological infrastructure, the utilization of BIM software, and the capability to integrate project information systems. Institutionally, the success of BIM implementation is strongly influenced by regulatory support, government policies, and the presence of standards and contractual frameworks that facilitate the application of BIM.

This model further demonstrates a causal relationship in which low readiness in any one dimension may lead to a fragmented project management system, ultimately reducing the effectiveness of cost control. On the other hand, when all three dimensions are fulfilled simultaneously, BIM implementation can operate optimally and create a cost control system that is more adaptive, integrated, and responsive to change, especially during crisis conditions. Thus, this conceptual model emphasizes that BIM implementation requires a systemic approach that focuses not only on technology but also encompasses comprehensive organizational transformation and institutional support. This model can serve as a foundation for developing BIM implementation policies in developing countries and as a framework for evaluating digital readiness in public construction projects.

Conclusion

This study indicates that the readiness for implementing Building Information Modeling (BIM) in controlling the costs of public construction projects in Timor-Leste is still in its early stages, yet it holds significant strategic implications, particularly in addressing crisis situations. Key findings reveal a gap between the high perceived benefits of BIM and the low level of implementation on the ground, which results in suboptimal project cost control. This indicates that digital transformation in construction cannot rely solely on technology but requires systemic readiness encompassing human resources, infrastructure, and institutional aspects simultaneously. The practical implications of this study emphasize that BIM implementation in public construction projects requires a structured and comprehensive strategy. The government needs to develop national BIM regulations and standards and integrate them into project contract documents. Construction organizations also need to increase investment in technology infrastructure and human resource capacity through BIM training and certification. Furthermore, a shift in organizational culture from conventional systems to digital-based systems is a key factor in the successful implementation of BIM. In crisis situations, BIM can serve as a strategic tool to enhance a project’s responsiveness to real-time cost changes.

Theoretically, this study contributes to the advancement of construction management research by highlighting that the successful adoption of digital technologies such as BIM is shaped by the interaction of technical, structural, and institutional factors. Accordingly, the approach applied in this study strengthens a systemic perspective in understanding digital transformation within the public construction sector. Although the study provides important findings, several limitations should be acknowledged. First, the limited number of respondents and the concentration on a particular region in Timor-Leste reduce the generalizability of the findings. Second, the qualitative approach used in this research was not able to quantitatively assess the magnitude of BIM’s impact on project cost efficiency. Third, this study focuses primarily on implementation readiness and does not comprehensively examine the operational stages of BIM in actual construction

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projects. Therefore, future research is recommended to use a mixed-methods approach, expand the scope of locations, and empirically test BIM implementation models to obtain more comprehensive and generalizable results.

References

1. A. K. T. L. Tobing, F. Rahmasari, and Hidayati, "Meta-Analisis: Aspek-Aspek Pemicu Pembengkakan Biaya (Cost Overrun) Dalam Proyek Konstruksi," Jurnal Teknik SILITEK, vol. 6, no. 01, pp. 86–101, 2026, doi: 10.51135/ntzhx451.
2. S. Dong, M. Ahmed, and V. Chatpattananan, "Analysis Of Key Factors Of Cost Overrun In Construction Projects Based On Structural Equation Modeling," Sustainability, vol. 17, no. 5, p. 2119, 2025, doi: 10.3390/su17052119.
3. A. M. Abdelalim, A. M. Kenawy, K. M. Aman, and S. Saeed, "The Role Of Site Layout Planning In Reducing Construction Project Costs," Engineering Research Journal, vol. 184, no. 2, pp. 65–89, 2025, doi: 10.21608/erj.2025.326158.1119.
4. G. M. Ningrum and U. Ulfa, "Analisis Metode Akuntansi Biaya Dalam Pengendalian Produksi," Indonesian Journal Of Accounting And Business, vol. 6, no. 2, pp. 35–49, 2025, doi: 10.33019/ijab.v6i2.132.
5. P. S. Puah, A. Purwantoro, and S. A. K. A. Uda, "Peningkatan Manajemen Konstruksi Melalui Integrasi Digital Technology," Journal Of Information System And Technology, vol. 5, no. 3, pp. 74–79, 2024, doi: 10.37253/joint.v5i3.10010.
6. W. B. Megawati and H. Purwanto, "Perbandingan BIM Dengan Konvensional Pada Hasil BQ Proyek X," Journal Of Applied Civil Engineering And Infrastructure Technology, vol. 3, no. 2, pp. 1–9, 2022, doi: 10.52158/jaceit.v3i2.247.
7. D. Mahardika and A. C. Windari, "Implementasi Building Information Modeling Pada Proses Tender Proyek Infrastruktur," Innovative: Journal Of Social Science Research, vol. 5, no. 1, pp. 2455–2462, 2025, doi: 10.31004/innovative.v5i1.17612.
8. R. Hidayat and A. Susanto, "Transformasi Digital Perencanaan Proyek Konstruksi: Perbandingan BIM Dan Metode Konvensional Terhadap Efisiensi Biaya Dan Waktu," Cerdika: Jurnal Ilmiah Indonesia, vol. 5, no. 11, pp. 2586–2594, 2025, doi: 10.59141/cerdika.v5i11.3261.
9. A. F. Kineber, S. Othman, D. J. Oke, N. Chileshe, and M. M. Buniya, "Identifying And Assessing Sustainable Value Management Implementation Activities In Developing Countries: The Case Of Egypt," Applied Sciences, vol. 13, no. 6, p. 3426, 2023, doi: 10.3390/app13063426.
10. C. El Hajj, G. Martínez-Montes, and D. Jawad, "An Overview Of BIM Adoption Barriers In The Middle East And North Africa Developing Countries," Engineering, Construction And Architectural Management, vol. 30, no. 2, pp. 889–913, 2023, doi: 10.1108/ECAM-05-2021-0432.
11. Sarju, D. V. Asmarayani, and N. C. Kresnanto, "Implementasi Konsep Building Information Modeling (BIM) 3D Dalam Mendukung Pengestimasian Biaya Pekerjaan Struktur," Jurnal Teknik Sipil, vol. 16, no. 4, pp. 247–260, 2022, doi: 10.24002/jts.v16i4.5454.
12. Sugiyono, Metode Penelitian Bisnis: Pendekatan Kuantitatif, Kualitatif, Kombinasi, Dan R&D, 3rd ed. Bandung, Indonesia: Alfabeta, 2017.
13. A. F. Kineber, I. H. A. M. Ghanem, H. Zaher, M. Hammad, and S. Saber, "Barriers To Implementing Lean Construction Practices In Egypt: PLS-SEM Approach," Frontiers In Built Environment, vol. 10, p. 1442184, 2024, doi: 10.3389/fbuil.2024.1442184.
14. M. A. Bukit and E. A. Saut, "Digitalisasi Metode Konstruksi Pada Proyek High-Rise Building: Akselerasi Waktu Dan Efisiensi Biaya Melalui Implementasi Drawing, Scheduling, Dan Estimasi Biaya Menggunakan Building Information Modelling," CRANE: Civil Engineering Research Journal, vol. 7, no. 1, pp. 1–12, 2026, doi: 10.34010/crane.v7i1.16435.
15. T. E. Pamungkas and A. Setiawan, "Perancangan Ruang Operasi Berbasis IPD Dan BIM Untuk Meningkatkan Kinerja Desain," JMTS: Jurnal Mitra Teknik Sipil, vol. 7, no. 3, pp. 795–806, 2024, doi: 10.24912/jmts.v7i3.29200.
16. A. Carina, A. Setiawan, and M. A. Yusuf, "Implementasi BIM Dalam Integrated Project Delivery Untuk Menentukan Kompensasi Risk/Reward Studi Kasus: Mosaic Centre, Kanada," Jurnal Civil Engineering Study, vol. 5, no. 02, pp. 79–88, 2025, doi: 10.34001/jces.v5i02.1411.
17. I. K. B. W. Mahatama, I. P. A. Sanjaya, and A. A. D. P. Dewi, "Paradoks Adopsi BIM Di Indonesia: Tinjauan Sistematis Atas Efisiensi, Hambatan, Dan Implikasi Kebijakan," Jurnal Spektran, vol. 13, no. 2, pp. 52–58, 2025, doi: 10.24843/SPEKTRAN.2025.v13.i02.p01.
18. F. D. Saputra, "Integrasi Rencana Desain, Anggaran Biaya, Dan Scheduling Pada Proyek Perkantoran Berbasis BIM," SINERGI: Jurnal Riset Ilmiah, vol. 3, no. 1, pp. 481–484, 2026, doi: 10.62335/sinergi.v3i1.2304.
19. A. R. P. Purba, F. Safura, and P. D. Saputra, "Penilaian Efektivitas Implementasi Building Information Modelling Dalam Meningkatkan Efisiensi Dan Kolaborasi Pada Proyek Konstruksi," Construction And Material Journal, vol. 7, no. 2, pp. 211–229, 2025, doi: 10.32722/cmj.v7i2.7868.
20. D. Sebastian and F. J. Oei, "Penyebab Dan Tindakan Mitigasi Pembengkakan Biaya Pada Proyek Konstruksi," Jurnal Media Teknik Sipil, vol. 23, no. 1, pp. 33–42, 2025, doi: 10.22219/jmts.v23i1.39634.
21. M. A. Wibowo, J. U. D. Hatmoko, and G. Satria, "Implikasi Integrasi BIM Dan ERP Terhadap Pengendalian Volume Pekerjaan Proyek," TEKNIK, vol. 45, no. 1, pp. 128–138, 2024, doi: 10.14710/teknik.v45i1.59484.
22. N. E. Safkaur, "Implementasi Green Building Pada Proyek Konstruksi Di Manokwari Dengan Pendekatan Lean Construction," Scripta Technica: Journal Of Engineering And Applied Technology, vol. 1, no. 1, pp. 48–58, 2025, doi: 10.65310/mansz354.
23. J. F. Putri and A. Setiadi, "Strategi Transformasi Digital Arsitek Kontemporer Berdasarkan Model Bisnis (2020–2024)," Jurnal Arsitektur Kolaborasi, vol. 5, no. 2, pp. 163–172, 2025, doi: 10.54325/kolaborasi.v5i2.103.
24. S. T. Putri and A. Setiawan, "Implementasi BIM Dalam Framework Integrated Project Delivery Untuk Meningkatkan Efektivitas Proses Desain RS Dharma Husada, Kediri," Jurnal Kajian Teknik Sipil, vol. 10, no. 2, 2025, doi: 10.52447/jkts.v10i2.8534.
25. I. K. B. W. Mahatama and I. P. A. Sanjaya, "Integrasi BIM-IoT Dalam Konstruksi Indonesia: Analisis Studi Kasus Komparatif," Jurnal Spektran, vol. 14, no. 1, pp. 23–33, 2026, doi: 10.24843/SPEKTRAN.2026.v14.i01.p03.
26. M. R. Fanani and A. Setiawan, "Implementasi BIM Dalam Integrated Project Delivery Untuk Menentukan

Kompensasi Risk/Reward Studi Kasus: Mosaic Centre, Kanada," Jurnal Lingkungan Binaan Indonesia, vol. 13, no. 4, pp. 207–216, 2024, doi: 10.32315/jlbi.v13i4.415.

27. C. A. Prastya, I. Hendriyani, and R. Pratiwi, "Implementasi Building Information Modelling (BIM) 5D Pada Estimasi Volume Dan Biaya Pekerjaan Struktur," Bandar: Journal Of Civil Engineering, vol. 7, no. 1, pp. 17–24, 2025, doi: 10.31605/bjce.v7i1.4301.
28. J. S. Ramadhan and F. J. Oei, "Strategi Pengembangan Teknologi Digital Dalam Metode Kerja Di Industri Konstruksi Untuk Pembangunan Nasional," JMTS: Jurnal Mitra Teknik Sipil, vol. 7, no. 2, pp. 621–630, 2024, doi: 10.24912/jmts.v7i2.26777.
29. R. M. Rizqy, N. Martina, and H. Purwanto, "Perbandingan Metode Konvensional Dengan BIM Terhadap Efisiensi Biaya, Mutu, Waktu," Construction And Material Journal, vol. 3, no. 1, pp. 15–24, 2021, doi: 10.32722/cmj.v3i1.3506.