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BIM Cost Management: ROI on BIM Implemented Projects in the Construction Industry

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Abstract – This study investigates the return on investment (ROI) of Building Information Modelling (BIM) in the construction industry and addresses common barriers to its adoption such as high start-up costs and lack of familiarity with the technology. Despite its proven potential to improve efficiency and profitability, many firms are hesitant to implement BIM. To address this, the research emphasizes the importance of demonstrating the long-term cost savings and strategic benefits associated with BIM adoption. A comparative analysis of construction projects, one using BIM and one not, was conducted to quantify the financial impact of BIM. The findings reveal significant differences in terms of cost efficiency, project coordination and overall return on investment. In addition, the existing literature was reviewed to identify the key factors influencing ROI, including stakeholder involvement, project scale and technological investment. The results underline the capacity of BIM to deliver quantifiable value and advocate for its wider application across the sector. By closing the knowledge gap on BIM-related ROI, this study supports the transition to BIM as a standard practice and provides insights for decision makers aiming to optimize construction outcomes.

Keywords – Building Information Modelling (BIM), Return on Investment (ROI), Construction Industry, Cost Efficiency, Project Comparison, Technology

I. Introduction

Building Information Management (BIM) has revolutionized the construction industry by moving from traditional 2D designs to advanced 3D digital representations of the physical and functional characteristics of buildings [1]. Initially developed alongside the first computer-aided design (CAD) systems, BIM has evolved significantly since its inception. This evolution includes its expansion into scheduling, cost management and information management, presenting the potential to enhance decision-making throughout the entire lifecycle of a building. Despite its growth, the construction industry has been slower to adopt these innovations compared to other sectors where traditional 2D designs have persisted for much longer [2-3]. The slower adoption of technological innovation in the construction sector compared to other sectors is due to several key factors. The complexity and fragmentation of projects, involving multiple stakeholders and processes, hinders the integration of new technologies [4]. In addition, there are significant upfront costs and uncertain returns on investment in hardware, software and training. An entrenched traditional culture and resistance to change among employees, who often see technology as a threat to their jobs [5]. Regulatory and security concerns also play a role, as organizations are reluctant to adopt tools that do not meet standards or require significant workflow changes. Finally, the level of technological literacy of the sector's workforce varies and requires extensive training for effective implementation [6].

BIM, which started to be used in the construction industry in the early 2000s, started as a tool for pilot projects. Early applications, such as clash detection and 3D visualization, laid the groundwork for its wider integration into tasks such as data management and cost analysis. Today, the benefits of BIM extend far beyond design and construction [7]. It is increasingly used in maintenance, facilities management, refurbishment and demolition processes, with an emphasis on sustainability and efficient end-of-life resource management. A key strength of BIM is its role as a digital repository of semantically enriched building models. These models include geometric representations and embed functional and topological attributes, facilitating advanced analysis such as energy performance, environmental impact assessment and asset tracking [8-9]. By supporting interoperability across software and disciplines, BIM enables collaboration between architects, engineers, contractors and facility managers. Its development highlights a paradigm shift in the construction industry, moving from siloed processes to integrated workflows that optimize resources and improve the performance of buildings over their entire lifecycle [10-11].

Developed through a literature review and case study, this study analyses the measurable strategic benefits and the ROI of BIM in the construction industry. Addressing gaps in previous research, such as the limited exploration of BIM's potential and the lack of standardized ROI metrics, the study presents a structured approach to quantifying the financial impact of BIM. A notable contribution is the ROI calculation for a specific project in the case study, which shows a significant reduction in revision costs. The analysis showed a return on investment of 502% for the second phase of the project using 3D as-built BIM, and 580% when applied over the entire lifecycle. These results demonstrate the transformative potential of BIM and provide a framework for financial evaluation and strategic implementation in construction projects.

II. Literature Review

The development of BIM has been shaped by several important advances in technology and methodology. Early research by Eastman [12] emphasized the capacity of BIM to serve as a comprehensive digital representation of a building, encompassing both its physical structure and its functional characteristics. Eastman argued that BIM is more than a collection of geometric objects; it also includes the relationships between these objects and enables advanced analysis, cost estimation and other applications that support more efficient project management.

Azhar [13] further expanded the definition of BIM, emphasizing that BIM is not only a software tool, but it is also a process that transforms workflows, project management and project delivery. BIM supports the concept of Integrated Project Delivery (IPD), a collaborative approach that aims to optimize efficiency and reduce waste at every stage of a building's life cycle. This is under the work of the Centre for Integrated Facilities Engineering (CIFE) at Stanford University, which introduced the concept of Virtual Design and Construction (VDC) as a foundation for BIM in 2001 [14].

The construction industry's interest in BIM has grown steadily due to its ability to save resources during the design, planning and construction phases. However, some confusion remains about the true nature of BIM. While some stakeholders consider it primarily as a tool for visualization and cost estimation, others, as noted by CIFE, consider BIM as a broader framework integrating Product, Organization and Process (POP) models [15]. From a technical perspective, BIM can be categorized into two types of applications: data import applications that capture and process information, and data output applications that provide reports or analyses, such as structural assessments or energy performance evaluations. These applications rely on structured data exchanges to enable interoperability between different software systems, a critical aspect of BIM's functionality [16].

Recent literature has also focused on the application of BIM in the life cycle management of both new and existing constructions. The process of creating BIM models for new constructions typically covers several phases from initial design to final delivery. For existing constructions, BIM can be updated or reconstructed through costly and time-consuming processes such as reverse engineering or laser scanning, especially in older European buildings where digital documentation is often not available [17-18].

Research increasingly emphasizes the ROI of BIM adoption, particularly in terms of cost savings, increased productivity and reduced errors. Studies have identified several factors that contribute to ROI, including conflict detection, reduced requests for information (RFIs), less rework and better general project coordination. However, the precise components of BIM-related costs and returns have not always been clearly identified in literature. This paper aims to address this gap by comparing two real construction projects and analysing the impact of BIM on their financial results.

In conclusion, while the potential of BIM to improve construction project outcomes is widely recognized, its full value is still being explored. Factors such as project scale, complexity and stakeholder involvement all influence the effectiveness of BIM implementation. This study presents a systematic approach to assessing the return on investment of BIM, focusing on emerging technologies such as digital documentation. The findings underline the importance of strategic planning and project-specific considerations when adopting BIM in the construction industry.

It is summarized that how to measure the impact of BIM on construction projects using key performance metrics across various dimensions:

Project Timeline Metrics: Evaluate schedule adherence/time savings. High adherence/time reductions demonstrate the role of BIM in efficient project planning and execution [19].

Cost Metrics: Assess budget variance and cost savings. This defines financial performance and quantifies savings from BIM through less rework and fewer change orders [20].

Quality Metrics: Monitor error rate and change order frequency to ensure project quality meets standards and assist in identifying areas for improvement [21].

Collaboration Metrics: Measure teamwork, stakeholder engagement, communication efficiency, effectiveness and satisfaction scores throughout the project [22].

Training and Adoption Metrics: Track training hours and adoption rates to assess team readiness and effectiveness of BIM integration [23].

Sustainability Metrics: Measuring material waste reduction and energy efficiency to assess the environmental impact and sustainability contributions of BIM [24].

Risk Management Metrics: Track risk mitigation effectiveness and incident frequency to improve security and compliance through proactive risk management [25].

Lifecycle Metrics: Measure the long-term benefits of BIM in facilities management and cost efficiency by evaluating project lifecycle cost analysis [26].

Return on Investment (ROI) Metrics: Calculate the ROI of BIM investments to provide a financial assessment of its impact, helping to justify future BIM initiatives [27].

These metrics provide a view of BIM's impact on project performance, helping to guide improvements and justify its adoption.

III. The ROI with BIM

BIM attracts attention as a technology that creates both cost increasing and saving effects in the construction sector in the long term. In the short term, BIM can increase expenses such as advanced software and hardware investments, training needs, process reengineering and initial data modelling costs. For example, when BIM is integrated into a project, it requires additional budget initially for team members to learn the technology and create a project-specific digital model. However, these costs are stabilized by savings in the long term and often provide better returns [28].

Long-term savings from BIM include reducing project revision costs, reducing rework rates through early detection of design errors, preventing material wastage on site and speeding up processes. For example, thanks to clash detection in a project, points where systems such as pipework and power lines overlap can be identified before construction starts and the corrections that need to be made on site can be prevented

[29]. Another example is using 4D BIM to optimize project timing and make labour and equipment more efficient [30].The case analysis conducted as part of the research also confirms these benefits. In the project analysed, the use of 3D as-built BIM resulted in a high ROI of 502% in the second phase and 580% over the whole lifecycle. These gains show that BIM recovers initial costs and adds long-term economic value to projects. Therefore, both short-term cost-increasing effects and long-term strategic gains should be considered when assessing the impact of BIM on ROI.

Methodologies for Calculating ROI

Comparing similar construction projects, one using traditional methods and another using BIM, is a common approach to measuring the financial impact of BIM. This allows key variables such as costs, change orders and requests for information (RFIs) to be tracked [31]. Various economic methodologies, including ROI analysis, are widely used to calculate the potential benefits of BIM. Autodesk Revit, a prominent tool in the industry, is often used to calculate ROI, taking into account software costs and productivity changes, with a particular focus on the first financial year of implementation [32–33].

Azhar [34] emphasizes that ROI analysis remains a standard method for evaluating investments.

$$\left(ROI = \frac{earnings}{cost} \right)$$

The formula helps measure the feasibility of BIM implementation. A case study conducted by Boston-based mechanical contractor J.C. Cannistraro shows that collaborative BIM implementation saved 10-20% of total project costs by reducing change orders and RFIs [35].

Key Factors Impacting ROI

ROI calculations in construction, especially with BIM, need to take into account both direct and indirect costs. Direct costs include change orders and subcontractor fees, while indirect costs are associated with delays and schedule overruns, such as day-to-day contractor expenses, project management costs, and construction loan interest. For example, Giel at all. studied various projects through comparative studies at the University of Florida. The next methodology was to obtain data from RFI and change order records supported by bilateral interviews provided by the medium-sized general contractor (GC). The selected software platforms were Autodesk Revit Architecture, Structure and MEP. The selected projects were named A and C (without BIM) and B and D (with BIM support) projects. The projects were comparable in terms of size, scope, contract value, delivery method and type of construction [36].

Practical ROI Calculation Formula

According to Autodesk (Catalyst), Return of investment for the first year for a system shall be calculated according to the following formula taking the cost, labor, training and productivity changes into consideration. Equation gives the formula for the first year ROI calculation [37-38]:

$$\frac{\left(B-\left(\frac{B}{1+E}\right)x\ (12-C)\right.}{A\ x\ (B\ x\ C\ x\ D)} = The\ ROI\ for\ the\ First\ Year$$

Where:
A = Hardware and software cost
B = Monthly labor cost
C = Training duration (in months)
D = Loss of productivity during training (%)
E = Productivity increases after training (%)

This formula takes into account both the costs (software, training and lost productivity during the transition) and the potential gains from increased productivity once training is complete.

Autodesk conducted a sensitivity analysis that highlighted the critical impact of productivity losses and gains on ROI. Small changes in these variables caused significant variations in the ROI results. The analysis showed that the average ROI of BIM was just over 60%, which is appropriate for most IT investments [37]. Several case studies support the financial benefits of BIM. For example, Holder Construction Company reported a return on investment ranging from 229% to 39,900% on projects using BIM. Similarly, Giel et al. found that average BIM-related costs were around 0.55% of total construction costs, consistent with previous findings of significant savings from BIM investments [39]. Calculating the return on investment for BIM may seem complex at first, but it offers significant long-term benefits to the construction industry. By reducing errors, change orders and delays, BIM improves project efficiency and ultimately delivers cost savings. While resistance to new technology is common, ROI analysis helps justify the investment and enables stakeholders to understand the financial benefits that can be achieved by adopting BIM. Through comprehensive ROI studies, organizations can recoup their investment and position themselves for increased productivity and profitability on future projects.

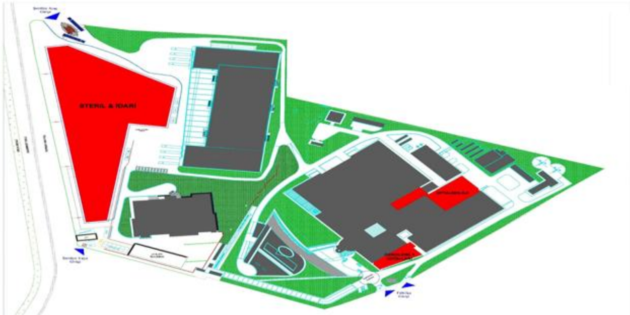
IV. CASE STUDY: BIM IMPLEMENTATION AND ROI IN A PHARMA FACTORY PROJECT IN ISTANBUL

This case study analyses the implementation of BIM in a pharmaceutical factory project in Istanbul, Turkey. The project was divided into three phases and a BIM ROI analysis was carried out to assess its impact on cost, time and project coordination. The pharmaceutical factory project has a total construction area of 59,885 m² divided into three phases. Each phase comprises approximately 20,000 m² of building area. Phases 1, 2 and 3 were completed sequentially and production activities were carried out in the respective areas. A shift in project strategy occurred with the introduction of BIM to address the challenges identified in Phase 1. Figure 1(a) shows the site plan of the new production facility, outlining its layout and key areas. Figure 1(b) presents the site plan of the entire factory campus, including the production facility and surrounding infrastructure.

General Information:

- Location: Istanbul, Turkey
- Land Area: 35,500 m²
- Construction Area: 60,000 m²
- Project Budget: €150 million (including process equipment)

a)



b)

Figure 1: (a) Site plan of the new production facility.

(b) Site plan of the factory campus.

Project Timeline by Phase:

- Phase 1: 36 months (without BIM)
- Phase 2: 25 months (3D as-built BIM)
- Phase 3: 18 months (full BIM implementation)

Phase 1: Traditional 2D Drawings and Initial Challenges

Traditional 2D drawings and project management by a consulting firm were used in Phase 1. However, as the project neared completion, significant conflicts arose between the architectural, structural, electrical, and mechanical disciplines. These overlaps necessitated extensive revisions, delays, and cost escalation. It was decided to move to BIM for subsequent phases.

Phase 2: Introduction of 3D As-Built BIM

A 3D model was created at a Level of Detail 300 as can be seen in Figure 2, and BIM was integrated into the construction process in Phase 2. Autodesk Revit was used for modeling, and clash detection analysis was performed to resolve conflicts between disciplines. Although this approach significantly improved coordination, unexpected changes during the construction process still led to additional conflicts. Despite these challenges, BIM's introduction led to notable efficiency gains compared to Phase 1.

BIM Costs in Phase 2:

- BIM management services for infrastructure setup and design.
- Modeling: Architectural, static, mechanical, and electrical systems were transitioned from 2D to 3D using Autodesk Revit Level of Detail (LOD) 300.
- BIM Consultancy: Ongoing support, weekly site visits, and coordination.
- Training: 10 hours of BIM training provided to employers and subcontractors.

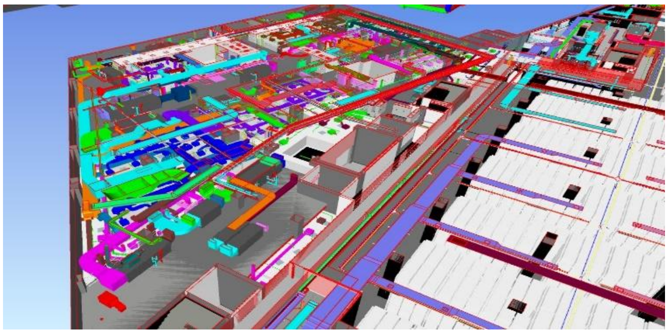


Figure 2: 3D model of a floor plan of Phase 2 sample project.

Phase 3: Full BIM Implementation

In Phase 3, the project moved to a fully integrated BIM process at a higher level of detail (LOD 500). Autodesk Revit and Navisworks were used to manage the entire construction process. All clashes identified in previous phases were resolved through coordination meetings, as BIM was mandatory for all subcontractors and project teams.

BIM Costs in Phase 3

Figure 3 shows an example of conflict detection, which identifies conflicts between different building elements in the project. This process helps to identify and resolve design issues before construction, leading to better coordination and efficiency.In addition to the costs of phase 2, phase 3 was also included:

- The Navisworks software fees for managing the project lifecycle.
- Updates and revisions were handled more effectively through clash detection.

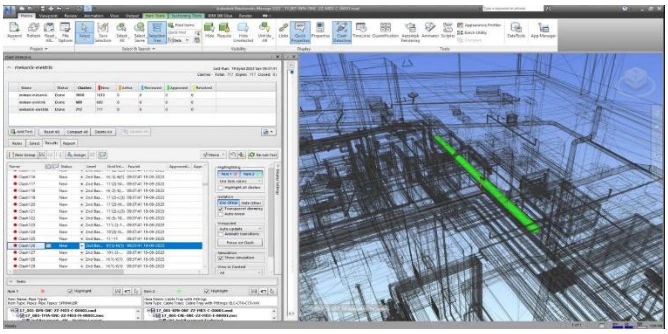


Figure 3: An example of a clash detection at the project.

BIM ROI Analysis

Within BIM, cost and time savings have been achieved through certain processes and technologies. Firstly, cost savings were achieved by eliminating incompatibility between designs from different disciplines before construction began through conflict detection. 3D modelling was used to eliminate the need for design revisions in the field, reducing the labor, material and equipment costs associated with these revisions. Using the accurate quantities provided by BIM, material management was optimized and wasted material was minimized. At the same time, 5D BIM integration enabled detailed budget planning and expenditure control.

Time savings were achieved by integrating 4D BIM into the construction planning and scheduling processes. This enabled a clearer visualization of the construction phases and effective planning of each phase. For example, by identifying dependencies in the workflow and simulating activities on site, unexpected delays were eliminated, allowing tighter management of the work program. In addition, the increase in design accuracy reduced the amount of time spent redoing work by the site team, thereby shortening the overall project duration. In this context, the systematic implementation of BIM has brought significant benefits in terms of both cost control and time management.

The introduction of BIM in Phases 2 and 3 resulted in significant cost and time savings.

Table 1: Comparison chart of Phase 1, Phase 2, and Phase 3 data

	Phase 1	Phase 2	Phase 3
Construction Area	20,000 m2	20,000 m2	20,000 m2
Project Duration	36 months	25 months	18 months
The BIM Cost	Without BIM	235,000 € (as-built only)	385,000 € (Full BIM)
Cost of revision	1,080,000.00 €	560,000.00 €	110,000.00 €

As shown in Table 1, in 3 very similar phases of the project, BIM was not used at all in the 1st Phase and took 36 months to be completed, in the 2nd Phase it was partially used limited to 3D modeling and completed in 25 months, and in the last 3rd Phase BIM was fully integrated and the project completed in 18 months. Since the average daily fixed cost of the construction site is €2000.

Time Savings

Phase 2 Daily Fixed Cost Saving: Saved €660,000 by reducing project duration for 11 months.

€2000 x 30 x (36 – 25) months = €660,000.00

Phase 3 Saving: Saved €420,000 by reducing project duration by an additional 7 months;

€2000 x 30 x (25 - 18) months = €420,000.00

The total cost saving of Phase 3 is;

€660,000.00 + €420,000.00 = €1,080,000.00

Revision Cost Savings

Project revision and design changes have been adequately avoided and the cost of revision has decreased by 520,000.00 € (€1,080,000.00 - €560,000.00) in the 2nd Phase of the project compared to Phase 1st Phase of the project, and decreased by €450,000.00 (€560,000.00 - €110,000.00) in the 3rd Phase of the project compared to the 2nd Phase of the project.

- Phase 2: Revision costs were reduced by €520,000 compared to Phase 1
- Phase 3: Revision costs were reduced by €450,000 compared to Phase 2

The total cost saving of Phase 3 is €520,000 + €450,000 = €970,000

ROI Calculation

When we compare the 3 phases of the project in general; we see that there is an additional BIM cost of 235.000 € in Phase 2 and (385.000 € - 235.000 €) = 150.000,00 € in Phase 3. However, as 3D as-built BIM was implemented in the 2nd Phase of the project;

- Phase 2 BIM ROI: (€660,000 + €520,000) / €235,000 = 502%

Since BIM was implemented from the beginning to the end of the Phase 3 and the project was managed by BIM throughout the whole project life cycle, most of the overlaps were prevented and about 870,000.00 € was saved only due to reduced/prevented overhead and revision costs.

- Phase 3 BIM ROI: (€420,000 + €450,000) / €150,000 = 580%

The analysis shows that BIM improves project efficiency and reduces costs in Phase 2 and Phase 3 of the pharmaceutical factory construction. Return on investment calculations reveal the benefits of adopting BIM methodologies. BIM provided a 502% return in Phase 2 and 580% return in Phase 3. These results underline the value of BIM in optimizing construction processes and reducing risks associated with design and implementation. This case study highlights the importance of integrating advanced modeling techniques to improve project outcomes in the construction industry.

V. Discussion and Conclusion

The This study developed through a literature of numerous articles and a case study that aims to analyze the measurable strategic benefits and key return factors associated with the return on investment of BIM in the construction industry. The key findings make it possible to develop new strategies to quantify the financial values of BIM. There is consensus on several important factors that allow us to propose a reasonable model based on this research. Some measurement techniques used in previous studies were identified:

1. Factors affecting BIM ROI without reported ROI results.
2. The ROI of BIM based on surveys.
3. Theoretical models based on assumptions.
4. Discussions that include case study limitations.

However, several major gaps emerged from previous studies:

- The failure to consider the potential and prevalence of using BIM in construction projects.
- The lack of consideration for tangible intangible return factors affecting BIM-based projects.
- The absence of a general industry standard for comparing BIM's ROI.

From the case study, it is observed that there is a remarkable decrease in project revision costs, along with earlier project completion times. BIM ROI was reported at 502% for the second phase of the project using 3D as-built BIM and 580% when used for the entire project lifecycle.

Key factors believed to impact BIM’s ROI include:

- Reducing conflicts
- Optimizing productivity
- Decreasing Requests for Information (RFIs)
- Minimizing the number of programs used
- Reducing changes and duplications
- Enhancing compatibility

In particular, phase 3 was completed approximately 7 months earlier than phase 2 and 11 months earlier than phase 1. This early delivery increased operational efficiency and company prestige, further increasing the ROI associated with the use of BIM. Measurement methodologies are required for further analysis of factors related to mitigation metrics such as schedule adherence, RFIs, change/repeat orders. These methods should address project-specific issues and external variables and ultimately increase the reliability of ROI results. This observation reinforces the idea that every construction project is unique.

While it is not possible to definitively assess the profitability of BIM on its own (given its more pronounced positive effects during the construction/implementation phases rather than the planning phase), all project stakeholders must realize the optimization potential of BIM. Therefore, BIM adoption should be mandated as a standard in projects. BIM maturity should become a key criterion in the tendering process for architects, engineers and contractors (AECs) in the construction industry. Over time, BIM is expected to become embedded across the industry and encourage its adoption among all parties involved.

For other stakeholders, the increasing use of BIM, particularly among project managers and contractors, suggests that existing successful business model components may not be sustainable in the long term. However, BIM offers the potential for revenue generation through new or modified data-driven business models or expanded data-based services. In this transitional phase, where not all competitors have adopted BIM, there is also the opportunity to price the use of BIM accordingly, and this can be seen as a cost position for the owner who is ready to capitalize on its high potential.

External variables such as work ethics and the quality of relationships between parties can also influence the BIM ROI of a project. As a result, it is not possible to provide a universal list of factors applicable to all construction projects. Instead, it is advisable to subclassify projects according to their characteristics, such as the scope of the building (infrastructure, commercial or private), location (municipal or non-municipal), site size or budget, and pre-construction, construction or post-construction phases.

It is believed that the study's results will assist academic researchers and BIM practitioners by providing up-to-date information to formulate effective strategies to measure the financial value of BIM in a concise manner. It is also expected it will enable deeper and broader research in the future and guide a more focused approach towards improving efficiency in the construction industry.

REFERENCES

[1] Eastman, Charles M. BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors. John Wiley & Sons, 2011.

[2] M. Gray, J. Gray, M. Teo, S. Chi, F. Cheung, Building Information Modeling, An International Survey, Brisbane, Australia, 2013.

[3] Doukari, Omar, Mohamad Kassem, and David Greenwood. "Building Information Modelling." Disrupting Buildings: Digitalisation and the Transformation of Deep Renovation. Cham: Springer International Publishing, 2023. 39-51.

[4] Penttilä, H.; Rajala, M.; Freese, S. Building Information Modelling of Modern Historic Buildings. In Proceedings of the Predictingthe Future, 25th eCAADe Conference Proceedings, Frankfurt, Germany, 26–29 September 2007; pp. 607–613.

[5] F. Leite, A. Akcamete, B. Akinci, G. Atasoy, S. Kiziltas, Analysis of modeling effort and impact of different levels of detail in building information models, Autom.Constr.20 (2011) 601–609.

[6] B. Becerik-Gerber, F. Jazizadeh, N. Li, G. Calis, Application areas and data requirements for BIM-enabled facilities management, J. Constr. Eng. Manag. 138 (2012) 431–442.

[7] C. Nicolle, C. Cruz, Semantic Building Information Model and multimedia for facility management, Web Information Systems and Technologies, Lecture Notes in Business Information Processing 2011. S. 14–S. 29.

[8] Sabol, Louise. "BIM technology for FM." BIM for Facility Managers (2013): 17-45.

[9] J. Lucas, T. Bulbul, W. Thabet, An object-oriented model to support healthcare facility information management, Autom. Constr. 31 (2013) 281–291.

[10] B. Becerik-Gerber, S. Rice, The perceived value of building information modeling in the U.S. building industry, ITcon 15 (2010) 185–201.

[11] A. Akbarnezhad, K. Ong, L. Chandra, Z. Lin, Economic and environmental assessment of deconstruction strategies using building information modeling, Proceedings of Construction Research Congress 2012: Construction Challenges in a Flat World, West Lafayette, USA, 2012, pp. S. 1730–S. 1739.

[12] Sacks, R., Eastman, C., Lee, G., & Teicholz, P. BIM handbook: A guide to building information modeling for owners, designers, engineers, contractors, and facility managers. John Wiley & Sons, 2018.

[13] Azhar, S. 2011. Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. Leadership and Management in Engineering, 11, 241-252.

[14] Kunz, J. & Fischer, M. 2012. Virtual design and construction: themes, case studies and implementation suggestions. CIFE, Stanford University, Stanford, CA, CIFE Working Paper.

[15] Kunz, John, and Martin Fischer. "Virtual design and construction." *Construction management and economics* 38.4 (2020): 355-363.

[16] T. Liebich, C.-S. Schweer, S. Wernik, Die Auswirkungen von Building Information Modeling (BIM) auf die Leistungsbilder und Vergütungsstruktur für Architekten und Ingenieure sowie auf die Vertragsgestaltung, BBSR, BBR, 2011.

[17] Volk, Rebekka, Julian Stengel, and Frank Schultmann. "Building Information Modeling (BIM) for existing buildings—Literature review and future needs." Automation in Construction 38 (2014).

[18] Y. Arayici, P. Coates, L. Koskela, M. Kagioglou, C. Usher, K. O'Reilly, Technology adoption in the BIM implementation for lean architectural practice, Autom.Constr.20 (2011) 189–195.

[19] Wefki, H., Elnahla, M., & Elbeltagi, E. (2024). BIM-based schedule generation and optimization using genetic algorithms. *Automation in Construction*, *164*, 105476.

[20] Lu, W., Fung, A., Peng, Y., Liang, C., & Rowlinson, S. (2014). Cost-benefit analysis of Building Information Modeling implementation in building projects through demystification of time-effort distribution curves. *Building and environment*, *82*, 317-327.

[21] Giel, B., & Issa, R. R. (2013). Quality and Maturity of BIM Implementation in the AECO Industry. *Applied Mechanics and Materials*, *438*, 1621-1627.

[22] Sacchettini, L. (2016). Key Indicators for Measuring BIM Collaboration Performance.

[23] Succar, B., Sher, W., & Williams, A. (2012). Measuring BIM performance: Five metrics. *Architectural Engineering and Design Management*, *8*(2), 120–142. https://doi.org/10.1080/17452007.2012.659506

[24] Azhar, S., & Brown, J. (2009). BIM for sustainability analyses. *International Journal of Construction Education and Research*, *5*(4), 276-292.

[25] Aladayleh, K. J., & Aladaileh, M. J. (2024). BIM-Based Risk Management to Optimal Performance in Construction Projects.

[26] Sajid, Z. W., Khan, S. A., Hussain, F., Ullah, F., Khushnood, R. A., & Soliman, N. (2024). Assessing economic and environmental performance of infill materials through BIM: a life cycle approach. *Smart and Sustainable Built Environment*

[27] Gharaibeh, L., Eriksson, K., & Lantz, B. (2024). Quantifying BIM investment value: a systematic review. Journal of Engineering, Design and Technology.

[28] Porwal, A., & Hewage, K. N. (2013). Building Information Modeling (BIM) partnering framework for public construction projects. Automation in construction, 31, 204-214.

[29] Luo, S., Yao, J., Wang, S., Wang, Y., & Lu, G. (2022). A sustainable BIM-based multidisciplinary framework for

underground pipeline clash detection and analysis. Journal of Cleaner Production, 374, 133900.

[30] Lee, J., & Kim, J. (2017). BIM-based 4D simulation to improve module manufacturing productivity for sustainable building projects. Sustainability, 9(3), 426.

[31] Das, K., Khursheed, S., & Paul, V. K. (2025). The impact of BIM on project time and cost: insights from case studies. Discover Materials, 5(1), 25.

[32] AUTODESK. White Paper ROI with Autodesk Revit Investment or Cost. Autodesk. [Accessed January 2016].

[33] Sepasgozar, S. M., Costin, A. M., Karimi, R., Shirowzhan, S., Abbasian, E., & Li, J. (2022). BIM and digital tools for state-of-the-art construction cost management. Buildings, 12(4), 396.

[34] Azhar, Salman, Malik Khalfan, and Tayyab Maqsood. "Building information modeling (BIM): now and beyond." Australasian Journal of Construction Economics and Building, The 12.4 (2012): 15-28.

[35] Salih Sen, The Impact of BIM/VDC on ROI: Developing a Financial Model for Savings and ROI Calculation of Construction Projects, Stockholm 2012.

[36] Giel, Brittany K., and Raja RA Issa. "ROI analysis of using building information modeling in construction." Journal of computing in civil engineering 27.5 (2013): 511-521.

[37] AIA & Rundell R., Calculating BIM's ROI, 22 September 2004.

[38] Rundell, R. (2006). “1–2–3 Revit: BIM and Cost Estimating, Part 1: How BIM can support cost estimating.” Cadalyst, August 7, 2006.

[39] Giel, Brittany Kathleen, R. Raymond A. Issa, and Svetlana Olbina. ROI analysis of building information modeling in construction. Diss. University of Florida, 2009.