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# Quantifying BIM investment value: a systematic review



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## Abstract

**Purpose** – Perceived benefits of building information modelling (BIM) have been discussed for some time, but cost–benefit benchmarking has been inconsistent. The purpose of this paper is to investigate BIM feasibility and evaluate investment worth to elucidate and develop the current understanding of BIM merit. The aim of the study is to propose a research agenda towards a more holistic perspective of BIM use incorporating quantifying investment return.

**Design/methodology/approach** – An in-depth examination of research patterns has been conducted to identify challenges in the assessment of the investment value and return on investment (ROI) for BIM in the construction industry. A total of 75 research articles were considered for the final literature review. An evaluation of the literature is conducted using a combination of bibliometric analysis and systematic reviews.

**Findings** – This study, which analysed 75 articles, unveils key findings in quantifying BIM benefits, primarily through ROI calculation. Two major research gaps are identified: the absence of a standardized BIM ROI method and insufficient exploration of intangible benefits. Research focus varies across phases, emphasizing design and construction integration and exploring post-construction phases. The study categorizes quantifiable factors, including productivity, changes and rework reduction, requests for information reduction, schedule efficiency, safety, environmental sustainability and operations and facility management. These findings offer vital insights for researchers and practitioners, enhancing understanding of 'BIM's financial benefits and signalling areas for further exploration in construction.

**Originality/value** – The 'study's outcomes offer the latest insights for researchers and practitioners to create effective approaches for quantifying 'BIM's financial benefits. Additionally, the proposed research agenda aims to improve the current limited understanding of BIM feasibility and investment worth evaluation. Results of the study could assist practitioners in overcoming limitations associated with BIM investment and economic evaluations in the construction industry.

**Keywords** Building information modelling (BIM), Investment value, Value management, Estimating, Construction

**Paper type** Research paper

## 1. Introduction

Building information modelling (BIM) is defined as the process of representing the physical and functional elements of a building digitally (Lee and Lee, 2020; Primasetra *et al.*, 2022). BIM creates a transparent environment that enables all project stakeholders to interact in a transparent manner by integrating multidisciplinary project teams into a shared platform (Hussain *et al.*, 2023). According to the architecture, engineering and construction industry, BIM refers to a design management methodology that links all phases of construction



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projects through the use of three-dimensional (3D) models (Condotta and Scanagatta, 2023; Hasanain and Nawari, 2022). As part of the BIM-based project management process, a 3D model is created which contains information on the geometric and non-geometric attributes of the building, as well as digital replicas of products from the manufacturer (Li *et al.*, 2023). Data are gathered into a shared data environment in which all project information is kept up-to-date and communicated to stakeholders in order to ensure the highest level of resource efficiency throughout the project life cycle (Feng *et al.*, 2023; Lu *et al.*, 2023).

BIM serves a multifaceted role encompassing visualization, cost estimation, scheduling, clash detection and collaborative data coordination, driven by its parametric capabilities (Khanzode *et al.*, 2008; Krystallis *et al.*, 2019; Love *et al.*, 2013). As a solution to address fragmentation, complexity and high-risk challenges within the construction supply chain, researchers advocate for BIM adoption (Sánchez *et al.*, 2022; Zakeri *et al.*, 2023). Given the intricate nature of construction projects involving numerous stakeholders, uninterrupted material flow, concurrent activities at shared locations and extensive interdisciplinary coordination, 'BIM's significance is paramount (Kim *et al.*, 2020; Qian, 2012). The burgeoning attention towards BIM utilization is underscored by its proponents who extol its advantages, urging the industry to enhance its implementation efforts (Harris *et al.*, 2015; Sompolgrunk *et al.*, 2023). The 'industry's adoption of BIM is profoundly influenced by its recognition of the 'technology's financial benefits (Sánchez *et al.*, 2022). Demonstrating the value of a novel technology or business model to organizational decision-makers is a pivotal strategy for its promotion, making the quantification of 'BIM's value increasingly significant (Ardani *et al.*, 2022; Lee and Lee, 2020).

Having a thorough understanding of the business benefits of BIM can assist organizations in making informed decisions about whether to invest in BIM technology and how to implement it effectively (Ardani *et al.*, 2022; Cucuzza *et al.*, 2022; Gharaibeh *et al.*, 2022). An organization can evaluate the potential return on investment (ROI) and determine whether the benefits outweigh the costs by identifying the specific benefits that BIM can provide, such as cost savings, improved productivity and reduced errors. Further, a thorough understanding of 'BIM's business benefits will help organizations formulate a well-defined strategy for implementing BIM and maximizing its benefits (Azhar, 2011; Harris *et al.*, 2015). For example, if reducing construction errors is the primary objective, then BIM can be used to detect and coordinate clashes (Daszczyński *et al.*, 2022). Furthermore, if the organization is focused on reducing project costs, it may prioritize the use of BIM for material optimization and pre-fabrication (Yu *et al.*, 2022).

The industry may find it challenging to determine the investment value of BIM within their own organization owing to a number of factors (Ardani *et al.*, 2022; Qian, 2012). Currently, there is no standardized way to measure the benefits of BIM, and different organizations may define success differently (Lee and Lee, 2020). Further, evaluating the financial impact of BIM can be challenging, especially for smaller projects or those that have been completed over a long period of time (Kim *et al.*, 2022; Xenidis and Koukoulis, 2022). In addition to being a complex technology, 'BIM's benefits can be difficult to quantify, and there is also often a resistance to change (Love *et al.*, 2013). Even though perceived benefits using BIM have been discussed for quite some time, no consistent, cost–benefit benchmarking has been conducted. It is imperative that building industry professionals have access to cost–benefit information to take the step towards adopting BIM in accordance with their own internal strategies and innovation plans.

The purpose of the literature review presented in this paper is to conduct a comprehensive investigation into the feasibility of BIM and to assess its investment value. Through this endeavour, the research seeks to elucidate and enhance the existing knowledge regarding the merits of BIM adoption within the construction industry. The overarching aim of this study is to propose a research agenda that fosters a more comprehensive understanding of ’BIM’s feasibility, encompassing the quantitative assessment of its ROI.

## 2. Tangible and intangible effects of BIM

BIM impacts cannot be accurately translated into numerical values owing to several limitations (PWC, 2018). Measurement of BIM effects is based on various assumptions as compared to a situation in which it is not used (Sheikhkhoshkar *et al.*, 2018). This is evident is several previous publications in which an attempt to report numerical values for the BIM investment worth were made (Ardani *et al.*, 2022; Latiffi and Tai, 2017; Qian, 2012). However, these studies did not provide detailed descriptions of the assumptions and calculation processes used to derive these values. There is a wide range of numerical values reported in these cases; therefore, these results question the reliability of BIM applications and lead to a negative perception of them (Sánchez *et al.*, 2022). Another limitation of previous BIM investment evaluation studies is that it is difficult to propose a comprehensive BIM assessment methodology that considers all possible effects (Barlish and Sullivan, 2012; Tu *et al.*, 2023). In construction projects, BIM creates a variety of effects, and an integrated BIM evaluation should take all possible effects into consideration (Zakeri *et al.*, 2023). To determine the investment worth of BIM, effects must be converted into costs (Toan *et al.*, 2022). However, converting all of these effects into costs is virtually impossible (Krystallis *et al.*, 2019). Thus, any methodology that considers only the tangible effects that can be converted to costs suggests that the results are unreasonable or limited (PWC, 2018).

BIM benefits calculations face significant challenges as intangible effects, such as improving communication between participants, are difficult to convert into costs (Ardani *et al.*, 2022). In contrast to intangible effects resulting from BIM adoption, many previous studies focused on tangible effects as preventing rework, or reducing time, which are easily converted into costs (Lee *et al.*, 2018; Yu *et al.*, 2022). Measuring the intangible benefits of BIM can be challenging for several reasons (Primasetra *et al.*, 2022). These reasons include the lack of standardized metrics (Sheikhkhoshkar *et al.*, 2018), subjectivity (Kim *et al.*, 2020), the time frame required to evaluate these benefits (Zhang *et al.*, 2022) and the complexity of BIM (Condotta and Scanagatta, 2023). In addition, the subjective nature of these benefits and the difficulty of attributing them directly to the technology further complicates the process (Hosseini *et al.*, 2016). Intangible benefits include improved collaboration, better decision-making and improved project outcomes (Hussain *et al.*, 2023; Kineber *et al.*, 2023). These benefits may not have an obvious money value, making it difficult to measure their impact (PWC, 2018). Despite these challenges, understanding and measuring intangible benefits is crucial to gaining a comprehensive understanding of the overall impact of BIM on a project or organization (Ham *et al.*, 2018).

It is also vital that the industry acknowledges that the investment of BIM is a long-term investment, meaning that ’BIM’s value proposition extends beyond the static benefits realized during a single project (Primasetra *et al.*, 2022; Zhao *et al.*, 2022). A BIM-driven project will provide valuable knowledge and experience that can be applied to almost all future projects (Kim *et al.*, 2020). In addition, value runs along the complete life cycle of a construction project, which includes the design, construction, operation and maintenance of the facility (Feng *et al.*, 2023; Toan *et al.*, 2022). It is possible though that there may not be sufficient data to measure or elaborate on the life cycle benefits of BIM since the projects that have used it are relatively recent (Hussain *et al.*, 2023). Additionally, ’BIM’s true value can only be determined once all downstream activities have been considered (Motalebi *et al.*, 2022). The calculation of ROI and cost–benefit analysis (CBA) may prove to be quite a challenge when considering all aspects of construction from conception to demolition, and hence, several research studies focused on evaluating the benefits of a certain aspect solely to avoid the complexity of the overall life cycle (Hwang and Zhao, 2018; Sabbaghzadeh *et al.*, 2022; Won *et al.*, 2016).

A review of the existing literature indicates that there is no agreement on a methodology for calculating the true investment value of BIM. The broader and more in-depth examination of previous work in this area revealed that the economic impact of BIM is little known, apart from some general allegations that have been made in academic and industry resources. The existing and proposed methodologies may not be formulated in a way that will aid industrial organizations in assessing the perceived value of BIM tailored to their specific operations. As a result of examining the existing literature, several methodologies focused solely on specific attributes or specific cases or projects, but there is a lack of a comprehensive cost–benefit model that can measure the ROI of BIM throughout the entire construction supply chain life cycle. Hence, this study seeks to summarize the current state-of-the-art for capturing BIM investment value by conducting a bibliometric systematic literature review (SLR) to gather and align all methodologies available in the literature. It is anticipated that the results will assist in guiding a more targeted approach towards efforts to close the research gaps that remain in the calculations of BIM feasibility and ROI.

## 3. Systematic literature review

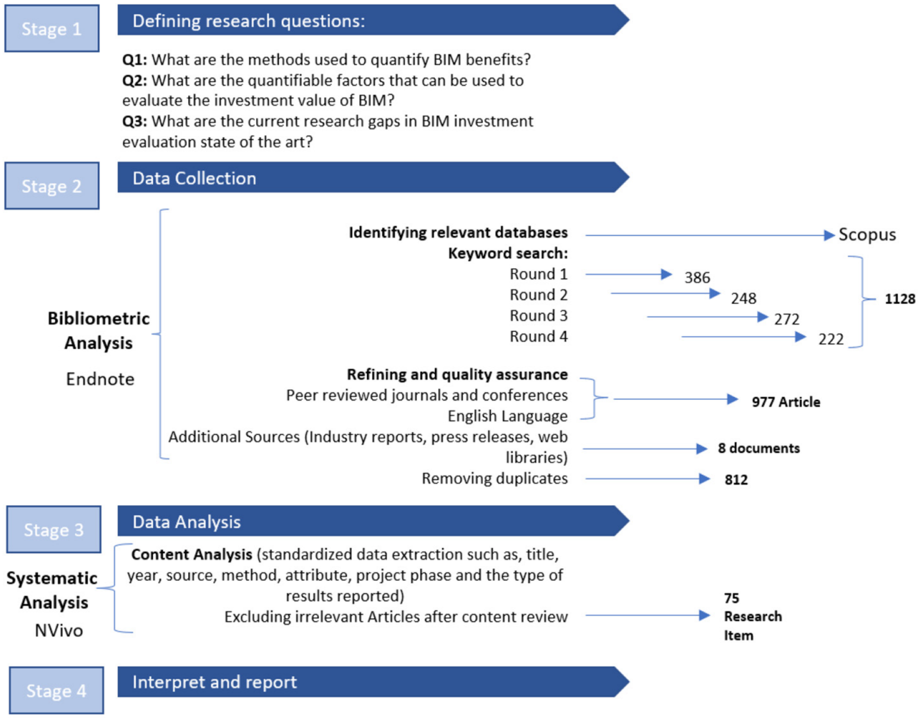
An in-depth and detailed examination of research patterns has been conducted to identify challenges in the assessment of the investment value and ROI for BIM in the construction industry. An evaluation of the literature is conducted using a combination of bibliometric analysis (quantitative research) and systematic reviews (qualitative research). In the context of an integrated review approach, conclusions derived from both quantitative and qualitative methods may be consolidated and validated, providing persuasive results in the event of discrepancies or contradictions between them (Kitchenham, 2004). Further, using this hybrid review approach provides the opportunity to examine research from a variety of perspectives, thus increasing the scope and depth of the conclusions derived from the review (Okoli, 2015).

An SLR is a methodical approach used to collect, analyse and summarize existing research pertaining to a specific topic or research question (Nightingale, 2009). Its goal is to offer a comprehensive understanding of the existing evidence and pinpoint areas where knowledge gaps exist. In this study, we use SLR to explore the current state-of-the-art in assessing the value of BIM investments and the methodologies used to quantify their benefits. The research follows a systematic methodology as described in Figure 1.

### *3.1 Defining the research questions*

The research strategy was initiated by identifying the research questions; the objective of the research is to summarize the current state-of-the-art for capturing BIM investment value by conducting an SLR to gather and align all methodologies available in the literature. The remaining of the research is directed towards answering three research questions as follows:

- *RQ1*. What are the methods used to quantify BIM benefits?
- *RQ2*. What are the quantifiable factors that can be used to evaluate the investment value of BIM?
- *RQ3*. What are the current research gaps in BIM benefits quantification?




**Source:** Authors' own creation

**Figure 1.** Flow diagram of research methodology

*3.2 Data collection*

Acquiring studies pertinent to the topic of this research was crucial, specifically utilizing bibliometric analysis to develop a quantitative understanding of the knowledge domain. The first step in collecting the relevant literature was to identify relevant databases. Compared to Web of Science and other databases, Scopus has more publications and quicker updates. Scopus was therefore selected as the source for literature search in this study. The keywords used are shown in Table 1, and since the literature covers a wide range of aspects and metrics spanning the entire project life cycle, a single keyword search was not adequate. Several iterations using different keyword selections were used to ensure the findings were adequate. Results were

| Round | Keywords |
|---|---|
| 1 | BIM, Rate of return, cost, investment |
| 2 | BIM, benefits, time, cost, sustainability |
| 3 | BIM, life cycle, implementation |
| 4 | BIM, rework, design, construction, waste |

**Source:** Authors' own creation

**Table 1.** Keywords search

screened and refined based on title, source, language and relevance after each keyword search.

*3.3 Inclusion criteria and quality assurance*

The articles selected for this review encompassed relevant publications from the past two decades, with a particular emphasis on the utilization of diverse assessment methodologies found in the literature. The chosen publication date range was deemed appropriate, given the well-established and enduring nature of economic methodologies. The review was confined to articles published in the English language.

To maintain consistency and ensure a high standard of review, we followed the customary practice of including only journal articles in our literature review, as recommended by Sompolgrunk *et al.* (2022). Journal articles, which typically present comprehensive and self-contained research findings, undergo multiple rounds of rigorous peer review. In contrast, conference papers often showcase preliminary research findings and may signify ongoing work to achieve specific research objectives. Although conference papers generally provide valuable insights, we made exceptions by including conference papers from reputable conferences that use a peer review process, following a manual quality assessment.

Consequently, most of the references cited in this paper originate from peer-reviewed publications featured in prominent international journals and conferences, known for their adherence to high standards of quality and rigor. Additionally, our review incorporates reports and case studies released by industry leaders and multinational corporations recognized for their excellence in research and innovation.

A total of 75 research articles were considered for the final literature review. A standardized data extraction form to record relevant information was made. From each article, both quantitative and qualitative data were recorded such as, title, year, source, method, attribute, project phase and the type of results reported.

## 4. Results

Figure 2 provides a visual representation of the distribution of the selected articles over the years. The search parameters encompassed articles published from year 2000 to the present day. The articles ultimately included in the study span the years from 2004 to 2023. It is worth noting that, at the time of this search, 14 articles scheduled for publication in 2023 were also incorporated into the analysis following a final screening process.

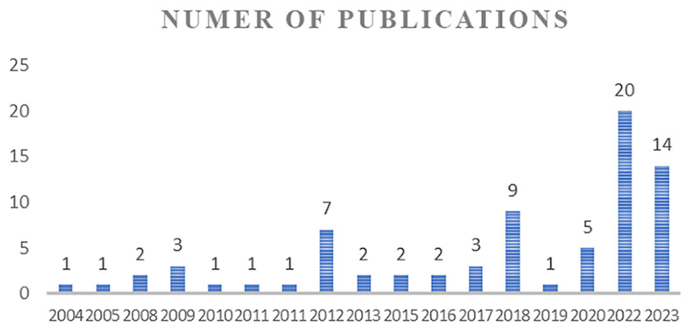



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**Figure 2.** Distribution of selected articles per year

This distribution pattern underscores the relatively recent emergence of interest in assessing the investment value of BIM. The trend depicted in the figure reflects an ongoing and expanding interest in this area of research, indicating its growing significance in contemporary discussions within the field.

Table 2 summarizes the classification of the reviewed literature; 72% of the sources were journal articles. The table mentions the journals in which several relevant publications were found, such as *Automation in Construction* had eight articles published on the topic of quantifying the benefits of BIM, whereas *Sustainability, Journal of Construction Engineering and Management* and *Journal of Civil Engineering and Management* had five, four and three articles, respectively. Eighteen percent of the reviewed articles were published in conference proceedings. As mentioned earlier, the conference articles were scrutinized to ensure presence of quality results. Seven other sources were included and were found to have essential content contributing to the subject, such as industry reports and case analysis that were performed as part of industrial research.

In prior literature, a consensus exists that BIM investment yields both tangible and intangible benefits and costs. This study encompasses all relevant research efforts that aim to quantify or understand the value associated with these tangible and intangible metrics. Therefore, it is imperative to scrutinize the research methodologies used in exploring the investment value of BIM to gain insight into past research trends. Figure 3 visually represents the methods used in the literature under analysis.

Additionally, the analysis examined the focus of the research according to the project phase. While quantifying the benefits and costs associated with adopting BIM technology allows for a more comprehensive understanding of both the benefits and costs associated with this technology, several studies have focused on a particular part of a project's life cycle to generate more significant results. Figure 4 illustrates the distribution of the analysed articles along the project life cycle.

Figure 5 summarizes the extracted quantifiable results from the analysed articles and lists the values that were identified in the literature for each attribute or factor. Content

| Journal articles | 72% |
|---|---|
| *Automation in Construction* | 8 |
| *Sustainability* | 5 |
| *Journal of Construction Engineering and Management* | 4 |
| *Journal of Civil Engineering and Management* | 3 |
| *Buildings* | 2 |
| *Energies* | 2 |
| *Energy And Buildings* | 2 |
| *Journal of Building Engineering* | 2 |
| *Journal of Information Technology in Construction* | 2 |
| *Waste Management* | 2 |
| Other | 22 |
| *Conference articles* | 18% |
| *Industry reports and research* | 10% |
| McGraw-Hill Construction | 2 |
| PWC | 1 |
| Other | 4 |
| Total | 75 |

**Source:** Authors' own creation

**Table 2.** Literature sources classification

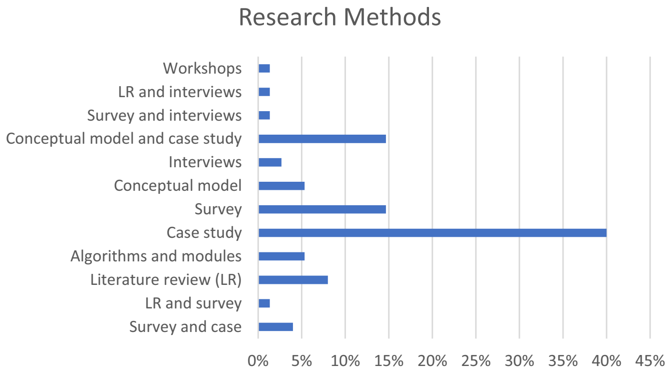


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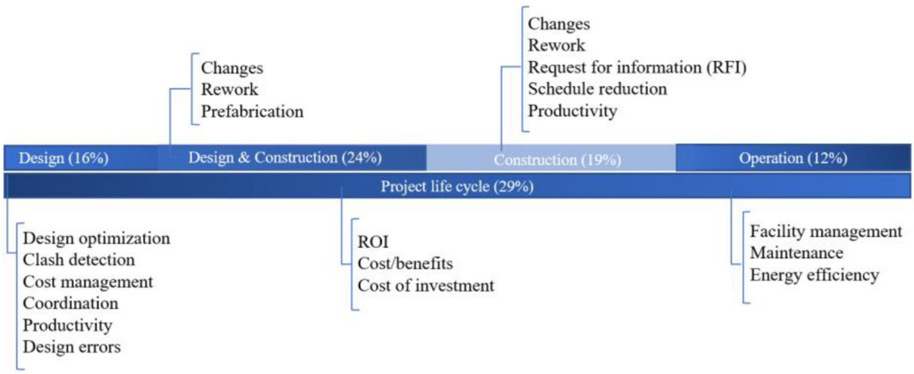
**Figure 3.** Research methods used in the analysed literature




**Source:** Authors' own creation

**Figure 4.** Distribution of the articles focus per project phase

analysis of each of the attributes is presented in the discussion section to provide more context of the derived conclusion.

## 5. Discussion

The remainder of the research is dedicated to addressing the research questions that have been identified, drawing upon the outcomes derived from the SLR analysis. Each research query is methodically answered and elaborated upon, taking into consideration the findings presented in the results section, and supplemented by a qualitative content analysis of the pertinent articles:

*RQ1*. What are the methods used to quantify BIM benefits?

As shown in Figure 3, several research methods were used in previous studies to quantify BIM benefits. A case study analysis was, not unexpectedly, the most commonly used method, as actual case studies are the most accurate method to obtain real values from construction projects in real life (Kim *et al.*, 2022). The analysis revealed that it is widely

| Measured Attribute Reported values |
|---|
| **ROI** |
| **Giel and Issa (2013)** ROI of BIM varied greatly from 16 to 1,654%, **Conde et al. (2020)** ROI of 34.5%, **Kim *et al.* (2020)** ROI of 145% & 350%, **Lee *et al.* (2012)** A BIM ROI of 22–97% was derived by converting 709 design errors detected by BIM into rework cost savings, **Lee and Lee (2020)** The integrated BIM ROI to consider the overall effect of applying BIM was about 476.72%, **McGraw-Hill (2012)** 62% of the targeted sample reported a positive ROI, **Stowe *et al.* (2015)** ROI of 1.8% to 10.5%, **Ham *et al.* (2018)** ROI of 94.41%, **Won and Lee (2016)** BIM ROI of 27% to 400%, |
| **Productivity** |
| **Abdelbary *et al.*(2020)** 50% reduction in labour works, **Conde *et al.* (2020)** productivity improvement exceeding 27%, **Poirier *et al.* (2015)** increase in productivity ranging from 75% to 240%, **Qian (2012)** Productivity Loss for Company ~2 Months Downtime, **Rafael Sacks (2005)** 2.3% improved work productivity, **Reizgevičius *et al.* (2018)** productivity gain after staff training 31%, **Sacks and Barak (2008)** productivity gain for drawing production of 21%–61%, **Succar *et al.*(2012)** productivity gains of 15% and 41%, |
| **Prefabrication opportunities** |
| **Banihashemi *et al.* (2018)** 50% increased possibilities for prefabrication, **Khanzode *et al.* (2008)** 100% pre-fabrication for the plumbing contractor, **Kuprenas and Mock (2009)** shop fabrication of $25,000, **McGraw-Hill (2012)** BIM increased prefabrication by 22%, |
| **Change orders and design errors** |
| **Abdelbary *et al.* (2020)** BIM resulting in rework cost reduction of 49 percent, A total saving of 10%, generated by BIM clash detection and 32% reduction of change orders, **Barlish; and Sullivan; (2012)** 42% reduction in change orders, **Giel and Issa (2013)** change orders was reduced by 40, 48, and 37%, **Ham *et al.* (2018)** rework due to design errors 5–20% in the total contract amount reduced by 47%, **Honnappa and Padala (2022)** 8.16% cost saving due to less changes, **Lee *et al.* (2018)** BIM impact on preventing rework $314,000, **Lopez (2012)** design errors were revealed to be 6.85 and 7.36% of contract value, **Love *et al.* (2013)** 10% saving in contract value through clash detection.<br>40% elimination of unbudgeted change, **Williams (2011)** changes reduced by 47%, |
| **RFI's** |
| **Abdelbary *et al.* (2020)** approximate reduction of 90% of RFI's, **Barlish; and Sullivan; (2012)** 30% in RFI's, **Conde *et al.* (2020)** reduced by 25%, **Giel and Issa (2013)** RFI's was reduced by 34%, 68%, 43%, |
| **Schedule** |
| **Abdelbary *et al.* (2020)** schedule reduction of 57, **Barlish; and Sullivan; (2012)** 67% less delays, **Honnappa and Padala (2022)** 11.52% time saving, **Khanzode *et al.* (2008)** 6 months' savings on the schedule, **Kuprenas and Mock (2009)** savings of time value of $10,000, **Love *et al.* (2013)** 7% reduction in schedule, **Paneru *et al.* (2023)** reduce the time to complete a project by 7%, **PWC (2018)** Time savings in design 6.3% and 36%, Time savings in build and commission 15.3%, Time savings in handover (12.5%), **Sacks and Barak (2008)** An overall reduction of between 15% and 41% of the hours required for a project, |
| **Environmental, sustainability, energy performance and waste management** |
| **Banihashemi *et al.* (2018)** reduction of waste by 2%, **Ferreira *et al.* (2023)** 2–5% savings in energy consumption, **Hasanain and Nawari (2022)** design optimization 20%–60% less water consumption, **Hussain *et al.* (2023)** Carbon emissions are reduced by 32.94%, 14.92%, 28.40%, and 6.52% during the production, construction, operation, and demolition stages, **Kamel and Kazemian (2023)** 26% lower energy use, **Motalebi *et al.* (2022)** 24%–58.2% reduction in energy consumption, **Tu *et al.* (2023)** construction waste source reduction of 67%, 48%, and 4.6%, **Won *et al.* (2016)** BIM-based design validation prevented 4.3–15.2% of waste on sites, |
| **Facility management and operations** |
| **Love *et al.* (2013)** cost of not using BIM is $680,000 over an asset's operating life, **PWC (2018)** Cost savings in asset maintenance (60.7%), **Tsantili *et al.* (2023)** reducing yearly energy usage by 43.75%, |
| **Project outcomes** |
| **Abdelbary *et al.* (2020)** A total saving of 10% ($10 million), generated by BIM, **Barlish; and Sullivan; (2012)** 5% savings n contractors' costs, **Conde *et al.* (2020)** 20% reduction in costs per project, **Kim *et al.* (2017)** BIM has contributed to identifying and/or resolving issues whose contractual values are as much as 15.92% of the total direct cost of the project, **Kuprenas and Mock (2009)** clash detection savings of $25,000, **Love *et al.* (2013)** 80% reduction in the time taken to generate a cost estimate with cost estimation accuracy within 3%, **Paneru *et al.* (2023)** decrease the time needed to generate a cost estimate by up to 80%, **PWC (2018)** 3.0% savings in total Cost savings in clash detection (1.8%), **Wong *et al.* (2018)** cost of drafting reduced by 80%–84% using BIM. |
| **Investment cost** |
| **Barlish; and Sullivan; (2012)** design costs: 31% increase, 29% increase in 3D background model creator costs: 34% increase, **Qian (2012)** Investments for BIM Costs (per staff) of ~S$18,000 to S$30,000, **Reizgevičius *et al.* (2018)** Expected productivity loss after starting to use BIM software 34%, |

**Figure 5.** Quantified values of BIM benefits from the literature

accepted that case studies are a popular method for quantifying the impact of BIM, due to their real-world context, in-depth analysis, insights into customization and ability to evaluate outcomes. Researchers and practitioners can better understand and optimize BIM implementation in the construction industry by using case studies that focus on individual projects and integrate rich data sources.

Researchers commonly use surveys and interviews to collect firsthand insights from professionals engaged in BIM implementation. Combining case studies with surveys and interviews enhances researchers' comprehension of 'BIM's influence, enabling them to incorporate both practical experiences and expert perspectives. Using this multi-method approach, researchers can attain a more comprehensive understanding of the impacts associated with BIM within the construction industry.

From design to construction to operations and maintenance, BIM impacts multiple phases of a project, and it can benefit a variety of stakeholders, including owners, designers, contractors and facility managers. Organizations can make informed decisions about whether to invest in BIM technology by quantifying its value for each of the phases and stakeholders and identify areas where BIM technology can be improved. Additionally, if organizations can quantify the value of BIM for the entire project life cycle and all stakeholders, they will be able to communicate the benefits of BIM more effectively to their clients, partners and other stakeholders, leading to increased adoption and increased project success. Figure 4 shows that 29% of the articles were not specific to a certain phase, rather the focus of those articles was to examine the ROI, the cost of the investment or a CBA generally.

Most of the research focused on the design stage, examined the effects of design optimization, reducing design errors, clash detections during the design stage and coordination between project stakeholders. Overall, 24% of the articles were focusing on design and construction integration, such as quantifying change orders costs, and the effect of BIM on enhancing opportunities for pre-fabrication and offsite construction. The effects of BIM on the post-construction phase had also received the attention of 12% of the analysed articles, in which the investment value was examined for operators and facility managers, in addition to a significant number of studies focusing on sustainability matters and optimizing energy consumption during the building operation:

*RQ2*. What are the quantifiable factors that can be used to evaluate the investment value of BIM?

To answer the research question regarding the quantifiable factors that can be used to evaluate the investment value of BIM from the literature, an in-depth analysis had been conducted to extract all factors that were quantified in the examined articles. The articles in which an integrated method was used such as ROI and CBA were also examined to extract the factors that were considered to implement these quantification methods.

### *5.1 Quantification of building information modelling investment value using return on investment method*

Several studies emphasized the importance of calculating BIM ROI to ensure that the construction organization understands the value of BIM. According to Sompolgrunk *et al.* (2022), ROI is a key principle for capturing the value of BIM. In addition to raising awareness of BIM ROI, the study is unique in providing a quantitative model which establishes the links and impact of various factors related to BIM ROI (Sompolgrunk *et al.*, 2022). The investment value of BIM has been recently assessed internally by construction firms by developing their own BIM ROI quantification method (Lee and Lee, 2020), However, a lack of data, complexity of analysis, an extended time frame, intangible benefits, difficulty measuring productivity improvements and an inability to apply economic principles make this difficult (Ardani *et al.*, 2022; Sompolgrunk *et al.*, 2022).

There is currently no defined methodology for calculating BIM ROI in the industry. Based on the review of articles that address BIM ROI, it is evident that every project has its own unique characteristics, a number of stakeholders involved and other factors that could influence a 'project's BIM ROI (Sompolgrunk *et al.*, 2022; Sompolgrunk *et al.*, 2023), and this is evident in the wide range of calculated ROI values from the literature. Figure 5 lists the identified ROI values in the analysed articles, and it can be stressed that the percentages vary significantly. However, all studies have reported a positive ROI value which emphasizes the fact that BIM will have a positive financial return on the project life cycle.

### *5.2 Quantification of building information modelling investment value using cost–benefit analysis*

Another method used in the literature to evaluate 'BIM's monetary impact is the CBA (Tu *et al.*, 2023). The ROI measures the financial gain or loss relative to the investment cost and is solely focused on the financial return (Barlish and Sullivan, 2012). The CBA, however, considers both the financial and non-financial benefits of an investment, such as enhanced safety (Ardani *et al.*, 2022). CBA provides a more comprehensive analysis of both financial and non-financial implications of BIM adoption, whereas ROI measures financial benefits such as reduced construction costs and improved productivity (Biancardo *et al.*, 2023; Love *et al.*, 2013).

As part of the CBA, all costs and benefits associated with BIM are identified and quantified, including those that are hard to quantify financially, such as improved safety, reduced rework and enhanced collaboration (Love *et al.*, 2013; Zakeri *et al.*, 2023). After comparing the benefits and costs, it is determined whether the investment is economically feasible (Sánchez *et al.*, 2022). A number of benefits have been found to result from the use of BIM in the analysed literature, including improved productivity (Poirier *et al.*, 2015), reduced construction costs (Yu *et al.*, 2022) and enhanced collaboration, all of which can contribute to a higher ROI (Chen *et al.*, 2022). The CBA involves calculating costs associated with the implementation of BIM, such as the cost of hardware and software, training and maintenance (Tu *et al.*, 2023). The result of the CBA is usually reported as a final value of the difference between the summation of costs deducted from the summation of benefits, such as the results of the study by Khanzode *et al.* (2008), which applied CBA to examine the value of BIM for a health-care project. The results reported $9m in savings for the overall project (Khanzode *et al.*, 2008). Another study by Kim *et al.* (2017) revealed that BIM has contributed to identifying and/or resolving issues whose contractual values are as much as 15.92% of the total direct cost of the project (Kim *et al.*, 2017). Nevertheless, the analysis showed that few studies applied the CBA and presented numerical results. The majority of the articles examined the CBA concept from a theoretical lens with qualitative results (Biancardo *et al.*, 2023; Hussain *et al.*, 2023; Zhang *et al.*, 2022).

### *5.3 Key attributes that were used in the literature to quantify financial impact of building information modelling*

Several studies have tried to capture the value of BIM by focusing on one attribute solely and converting the impact of this attribute into cost. The main attributes that were studied in conjunction to BIM benefits quantification in the analysed literature varied according to the projects phase as shown earlier in Figure 4.

### 5.4 Productivity and processes

The productivity aspect has been discussed in the literature from two perspectives. The first view is that BIM increases construction project productivity in both the design and construction phases (Love *et al.*, 2013; Poirier *et al.*, 2015), and the second view is that the initial stages of implementing BIM will result in a reduction in productivity as a result of training, changing processes and adjusting to the new system (Sacks and Barak, 2008; Succar *et al.*, 2012). Using BIM, project stakeholders can better communicate and collaborate, reduce rework costs and delays and get accurate and detailed information that streamlines construction processes and reduces project completion times.

The use of BIM has been shown to increase productivity and financial impact, according to some articles. As a result of reducing inefficiencies, improving communication and providing accurate and detailed information, BIM reduced labour work by 50% in a fast-track project (Abdelbary *et al.*, 2020). Another study claimed that productivity increased by 27% in the case of small commercial franchising projects (Conde *et al.*, 2020). The increase in productivity was also associated with BIM increasing the possibilities for pre-fabrication and off-site construction (Cucuzza *et al.*, 2022). McGraw-Hill concluded that BIM enhanced pre-fabrication opportunities by 22%, which resulted in higher overall project productivity (McGraw-Hill, 2012). Also, Poirier *et al.* (2015) found that modelled and pre-fabricated areas had an increase in productivity of between 75% and 240% over areas that were not modelled (Poirier *et al.*, 2015).

### 5.5 Changes, rework and design errors

Rework and design errors have always been regarded as major contributors to time and cost overruns in the construction industry. According to Abdelbary *et al.* (2020), rework increased project costs by 22% on average, resulting in a delay of 33 weeks on projects with an average planned duration of 156 weeks, a 23% delay from the original project value (Abdelbary *et al.*, 2020).

It has been reported that BIM reduces rework, minimizes changes and prevents design errors by allowing designers to identify and resolve potential conflicts and issues before construction begins, as well as detect clashes in the design before they occur (Ham *et al.*, 2018; Honnappa and Padala, 2022; Won *et al.*, 2016). As a result of BIM, communication and collaboration are enhanced, resulting in faster decision-making, fewer errors and streamlined construction. This attribute has been quantified in the literature by converting the positive impact of reducing changes and errors into cost savings, improved project timelines and higher-quality outcomes. Abdelbary *et al.* (2020) also examined how BIM reduces rework in fast-track projects, with a savings of 10% ($10m) due to prevention of change orders, generated by clash detection in BIM (Abdelbary *et al.*, 2020). An economic analysis of design errors in BIM-based high-rise projects (Ham *et al.*, 2018) quantified a reduction in rework by 5%–20%, resulting in 47% savings.

### 5.6 Requests for information

A typical construction project will involve numerous requests for information (RFIs) that can be time-consuming and expensive (Morales *et al.*, 2022). However, with the use of BIM, the number of RFIs can be greatly reduced (Toan *et al.*, 2022; Zakeri *et al.*, 2023). To prevent errors and omissions that would typically result in RFIs during construction, BIM allows construction professionals to collaborate and identify potential issues before construction begins (Tu *et al.*, 2023). BIM can also reduce the time required to respond to RFIs by providing a centralized platform for information sharing. Abdelbary *et al.* (2020) analysed several case studies and found that the use of BIM had reduced the number of RFIs by 90%. With all project data available in one place, the project team can respond to RFIs quickly and accurately, reducing time and costs (Morales *et al.*, 2022). Furthermore, BIM can make it easier to track RFIs and ensure timely resolution, which can help prevent delays and keep projects on schedule. A study by Barlish and Sullivan (2012) evaluated the time saved by reducing RFIs through BIM, and they noticed a reduction in the number of RFIs by 30%, with an evaluation of 5% cost savings and 67% less time delays (Barlish and Sullivan, 2012).

*5.7 Schedule reduction*

Overall, studies have consistently shown that the use of BIM can significantly improve productivity and save time and costs in the construction industry, making it a valuable tool for construction projects, in which time overruns have always been jeopardizing projects' performance. A report by McGraw-Hill Construction found that BIM can lead to a reduction in project costs and schedules by up to 50%, with the use of BIM leading to improved project coordination, fewer errors and omissions and a reduction in RFIs (McGraw-Hill, 2012). Another research proposed a BIM framework to quantify delays and cost overruns that are attributed to changes and found that BIM contributed to 11% of the time savings (Honnappa and Padala, 2022).

*5.8 Safety and environment*

There has also been significant literature regarding BIM's association with sustainability. First, it provides accurate and detailed information about building systems, such as HVAC, lighting and energy usage, which can help optimize building performance (Choi and Lee, 2023). Building designers can use this information to make more informed decisions regarding building design, energy efficiency and resource usage, resulting in sustainable and environmentally friendly buildings (Choi and Lee, 2023; Li *et al.*, 2023). Ferreira *et al.* (2023) examined the impact of design optimization using BIM and concluded that enhanced energy consumption can result in a 2%–5% total savings (Ferreira *et al.*, 2023). A similar study examined the optimization of design to achieve sustainability, in which BIM reduced water consumption in the building by up to 60% (Hasanain and Nawari, 2022).

Secondly, BIM can help reduce waste and increase efficiency in the construction process by allowing project teams to identify and resolve potential issues before construction begins (Hasanain and Nawari, 2022). This can help reduce the amount of material waste, energy usage and environmental impact associated with the construction process. Banihashemi *et al.* (2018) proposed a construction waste reduction workflow and demonstrated how BIM can save around 2% of additional waste (Banihashemi *et al.*, 2018). Similarly, a BIM-based design validation prevented 4.3%–15.2% of construction waste on sites according to Won *et al.* (2016).

*5.9 Operations and facility management*

BIM for operations and facility management applies BIM technology to effectively manage building facilities throughout their life cycle (Yu *et al.*, 2022). It optimizes asset management, space utilization, energy efficiency and sustainability while streamlining documentation and supporting emergency planning (Blampain *et al.*, 2023; Lu *et al.*, 2023). Facility management that integrates BIM reduces costs, improves performance and improves occupant satisfaction (Toan *et al.*, 2022). Sixty percent of respondents to a survey by PWC reported achieving cost savings in their asset management operations through BIM (PWC, 2018). Conde *et al.* (2020) proposed a simplified method for BIM implementation in operations and maintenance and concluded that significant time savings could be achieved through BIM for the facility management phase (Conde *et al.*, 2020):

*RQ3*. What are the current research gaps in BIM investment evaluation state of the art?

An analysis of previous research trends regarding BIM investment value is provided in this systematic review. Based on the analysis, gaps in the body of knowledge regarding BIM investment value and feasibility were identified. These gaps are as follows:

- There is a lack of an industry-established method for quantifying and benchmarking the BIM investment value.
- 'BIM's intangible benefits for construction projects are not sufficiently addressed.

Despite numerous studies examining the impact of BIM on productivity, cost savings and related metrics, there remains a lack of standardized methods for calculating its economic implications. This absence of a standardized approach poses challenges for construction professionals, particularly when justifying the associated costs of implementing BIM technologies—a significant investment in itself. Presently, many in the construction industry rely on case studies and project-specific data to evaluate the feasibility of BIM investments. However, these efforts remain fragmented, tailored to individual organizational processes and methodologies, making cross-industry result comparisons and benchmarking a complex task.

To address this issue and facilitate the quantification and benchmarking of BIM investment value, it is imperative to develop a standardized method. Such a method would not only aid construction professionals in making informed decisions regarding BIM technology adoption but also enable them to accurately assess the costs and benefits associated with its implementation.

Moreover, the application of standardized methods can serve to substantiate BIM investments when presenting proposals to stakeholders such as owners, investors and clients. Demonstrating the economic returns through standardized metrics can bolster the case for securing funding and garnering support for these initiatives.

Furthermore, the establishment of a standardized approach for quantifying BIM investments can foster innovation and advancement within the construction sector. Through the adoption of industry-wide standards for BIM implementation and investment value assessment, construction professionals can collaborate to identify and implement best practices, leading to enhanced utilization of these technologies and, ultimately, improved project outcomes. Therefore, the importance of a standardized method for quantifying and benchmarking BIM investments cannot be overstated, as it contributes to informed decision-making, funding acquisition, and industry progress.

Additionally, there exists a research gap that overlooks the financial evaluation of intangible benefits stemming from BIM implementation in construction projects, despite the potential for these benefits to yield superior project outcomes, heightened efficiency and enhanced long-term sustainability. In essence, BIM possesses the capacity to enhance project outcomes, boost efficiency and elevate long-term sustainability primarily through its intangible advantages. Construction professionals can attain a comprehensive understanding and recognition of the enduring value that BIM brings to their projects by duly acknowledging and addressing these intangible benefits.

BIM in construction projects may have intangible benefits that are difficult to quantify, but over time, they can have significant economic value. It is important to collaborate and communicate effectively in order to improve project outcomes and make better decisions, which can increase client satisfaction and lead to repeat business. A construction company can significantly increase revenue and profits by implementing this strategy. Visualizing and understanding project designs can reduce the likelihood of costly errors or rework, improving project timelines, reducing costs and improving quality. The resulting reduction in expenses and increase in efficiency can also have a significant impact on the bottom line of a construction company.

Similarly, improving efficiency and accuracy in project planning and execution can lead to long-term savings, increased productivity, and improved project outcomes by reducing the likelihood of costly mistakes or delays. Construction companies can benefit from this by increasing profits and improving their competitive position in the market. In addition, 'BIM's ability to provide accurate and detailed information can contribute to long-term economic benefits by reducing waste and minimizing the environmental impact of construction projects. Over time, this could lead to lower operating costs and greater value for buildings and infrastructure. Thus, by excluding the intangible factors and their economic value from the BIM investment value calculation, the construction industry is losing the opportunity to accurately measure 'BIM's economic impact.

## 6. Conclusion

In conclusion, this research has unearthed pivotal insights into the quantification of BIM benefits. Key findings include the identification of ROI calculation as the primary method for assessing 'BIM's tangible benefits. Two significant research gaps are highlighted: the absence of a standardized BIM ROI method and the limited exploration of intangible benefits. Quantifiable factors for BIM investment value assessment are categorized, encompassing productivity, changes and rework reduction, RFIs reduction, schedule efficiency, safety, environmental sustainability and operations and facility management. These specific findings provide actionable insights for researchers and practitioners, offering a clear road map for further exploration and development in the construction industry.

This research presents tangible contributions to the field of BIM. The identification of ROI as the primary quantification method and the spotlight on research gaps offer practical guidance for industry professionals. By addressing the absence of a standardized BIM ROI method, this research lays the foundation for streamlined decision-making in BIM technology adoption. The exploration of intangible benefits underscores the potential for enhanced project outcomes, efficiency and long-term sustainability. Categorizing quantifiable factors provides a road map for optimizing BIM implementation, leading to increased productivity, reduced costs, improved safety and environmentally conscious construction practices. These findings not only empower researchers and practitioners but also contribute to the industry's evolution towards more informed, sustainable and efficient construction practices.

In conclusion, the study recommends that future research be directed towards establishing a common method for measuring BIM investment value for industry use based on the identified gaps. As a result of such tool, the construction industry will become more aware of the feasibility of BIM, which will lead to more sustainable, productive and efficient benefits.

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## Further reading

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## About the authors

Lina Gharaibeh, Researcher in production technology focusing on supply chain and logistics, is from a construction management background, with a Bachelor of Civil Engineering and almost 12 years of experience in the construction sector. Skilled in project planning, construction management, project management, logistics and project delivery, as well as has a Master of Science – MSc focused on Construction Management. Since joining University West in March 2020 as a PhD student, Lina Gharaibeh has been investigating the digitalization and optimization of supply chain and logistics using BIM and Industry 4.0 technologies. Lina Gharaibeh is the corresponding author and can be contacted at: lina.gharaibeh@hv.se

Kristina Eriksson, Associate Professor in production systems, at University West, focusses on teaching and research in production logistics, supply chain management and simulation of production flows. Kristina Eriksson has substantial experience and educational and research interest in industrial work integrated learning, specifically flexible e-learning concepts for competence development in collaboration with industrial companies.

Björn Lantz, Professor in operations management at Chalmers and Visiting Professor in Logistics at University West, has worked in a number of different research areas over the years, for example, e-commerce, supply chain risk management, diffusion of innovations, queuing theory and quantitative research methodology. Their primary research area is healthcare production logistics where the focus is on different aspects of capacity management.