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BIM Utilization to Eliminate Claims, Risks, and Improve Productivity in Construction Projects

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Abstract

Delays, cost overruns, and disputes have traditionally plagued the construction industry. These issues arise from poor management and the complexities of construction projects. Given this situation, this research sought to identify and quantitatively prioritize the factors leading to claims/disputes, risks, and the construction activity productivity. At the same time, it aimed to measure the extent to which the BIM approach mitigates such factors. A mixed methodological approach was utilized, which included a structured questionnaire survey and two case studies. For quantitative data analysis, advanced techniques and tools of IBM SPSS and AMOS were used, which included mean analysis, Standard Deviation (SD), Relative Importance Index (RII), Confirmatory Factor Analysis (CFA), Exploratory Factor Analysis (EFA), and Structural Equation Modeling (SEM). The findings confirmed the hypothesis of this research, showing BIM implementation directly and substantially improves productivity, as evidenced by the 28% reductions in disputes, 31% in communication efficiency, and 24% in overall productivity. Moreover, SEM results confirmed the existence of positive causal relationships regarding BIM adoption and cost control, schedule compliance, and safe work performance. This study conclusively demonstrates that BIM is a dynamic management approach to enhancing stakeholder coordination, minimizing disputes, and ultimately ensuring project viability.

Keywords: Construction Management; Building Information Modelling (BIM); Claims and Disputes; Labor Productivity; Risk Management; Celsius and Grand Museum Project.

1. Introduction

The construction industry faces challenges due to organizational factors and technology issues, similar challenges that generally lead to increased costs and delays on projects. This can lead to increased risk and dissatisfied clients. BIM technology facilitates better project delivery and risk control within the construction field by improving stakeholder communication. BIM technology helps to alleviate these concerns by improving collaborative communication and the planning process [1]. The reduced risk of disputes, irrefutable constructive collaboration, and increased gains of productivity earned from positive labor strategies encourage the use of BIM technology [2, 3]. The existing literature on BIM technology addresses its essential role in the claims and disputes made within construction projects [4]. Specifically, previous research has confirmed that BIM enhances project control by increasing the transparency of information, clarifying designs, and minimizing changes to be made during implementation. BIM serves as an effective, it can foresee problems and simulate scenarios, making it possible for risk and loss to be decreased in a project at the

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decision-making process. The findings of this study are a valuable source that can be used in subsequent studies. They also open the door to the creation of better approaches to the management of construction projects and the implementation of their aims more efficiently.

The research will rely on empirical evidence based on practical case studies using BIM technology and thus offer concrete and measurable data to fill the current knowledge gap. This literature review observes that there are serious gaps in past research in the area of determining the impacts of Building Information Modelling on claims management, disputes, risk mitigation, and labor productivity in the construction sector. It notes the unavailability of empirical case analysis and the weaknesses of the previous quantitative research studies, especially because the respondents had little experience with both BIM tools and management of construction contracts. The review notes that it is important to create defined and standardized principles of BIM implementation agreed upon by stakeholders in the industry so as to ease the adoption, improve coordination, and minimize project risks.

The proposed research is expected to fill these gaps by creating a working process and a detailed list of checks that may be used as a management tool to ensure that claims do not turn into disputes, reduce project risks, improve labor productivity, and use real case studies that are based on BIM technology.

Most previous studies indicate that construction project delays, along with the associated risks and financial excesses, are primarily due to disputes and claims arising between contracting parties [5]. In this context, conceptual and methodological limitations of the current academic literature are associated with the theoretical challenges in the lack of integrated frameworks to integrate BIM with risk management and conflict management models. Practical challenges, in their turn, are based on the real-life issues of implementation, such as poor communication between the stakeholders, insufficient training, and difficulties with data interoperability.

Prior studies that employ a quantitative approach are limited in cadence and scope because many respondents are users of advanced BIM and are construction contract managers. In addition, there is a severe lack of empirical case studies. BIM literature has shown the need for some formal, mutual structuring and standardization of implementation principles that are collaboratively accepted by gateholders in the industry. Such unified principles would help facilitate and enhance adoption, improve the coordination between parties involved, and help in the mitigation of risks associated with a specific project. The proposed research aims to counter these by defining a validated work system and management checklist. In order to distinguish between the theoretical challenges and practical challenges, we should explicitly categorize and separate the research gaps and limitations discussed in the research into two distinct and clearly defined groups.

Theoretical Challenges (Literature - Based) are as follows:

- Limited exposure and experience of respondents with both sophisticated BIM tools and formal construction contract management processes.
- There is a notable scarcity of empirical case analyses, with a large portion of the available literature being theoretical or focused on prototype development, thereby limiting applicability to real-world construction projects.
- The literature highlights the necessity for defined and standardized principles of BIM implementation that are collectively agreed upon by key industry stakeholders. Such standardization is crucial for easing widespread adoption, improving inter-party coordination, and effectively minimizing overall project risks.
- Unavailability of empirical case analysis and the weaknesses of the previous quantitative research studies, especially because the respondents had little experience with both BIM tools and management of construction contracts.

Practical Challenges (Industry - Observed):

- Practical challenges, in their turn, are based on the real-life issues of implementation, such as poor communication between the stakeholders, insufficient training, and difficulties with data interoperability.
- There is no integrated system of collaboration between the different stakeholders of a project, including owners, designers, and architects, as well as engineers, contractors, subcontractors, facility managers, and building operators.
- Delays, conflicting information, or a lack of coordination among various disciplines.
- Design errors, unclear specifications, changing orders, and poor communication.

Unfavorable environmental and climatic factors, improper site preparation, inexperienced contractors, unforeseen extra costs, and lack of proper communication between the parties.

2. Literature Review

A body of existing literature has emphasized the significance of BIM in dispute prevention and dispute claims. The literature indicates essential BIM benefits concerning the enhancement of transparency during information transfer processes, the ease of clear understandings about designs and documents, and the prevention of unforeseen changes during construction processes. In addition, the successful utilization of BIM as a risk management process is well-supported in the literature, allowing for proactive predictions and scenario simulations for the development of knowledge-based decisions, ultimately contributing to loss prevention and mitigation at the financial level.

2.1. Disputes and Claims in the Industries of Construction

2.1.1. Causes of Claims and Disputes

Previous studies have suggested claims within construction projects are a result of a combination of various elements, including delays in the delivery of financial obligations, errors/oversights within designs, insufficiencies within technical drawings/specifications, and modifications within the process. Some of the elements that lead to heightened conflicts in the construction sector include unfavorable environmental and climatic factors, improper site preparation, inexperienced contractors, unforeseen extra costs, and lack of proper communication between the parties [6, 7]. The growing number of claims, as reported by Bakhary et al. [8], shows that there is an immediate necessity to develop an effective construction claims management system, as the contractors will then be tempted to use the contract dispute resolution option. Among the more noticeable sources of claims, there is the selection of contractors who have the lowest bids and are late in their payments. According to another study, the best method of minimizing claims is by a correct interpretation of their causes as a part of the contract terms and conditions [9]. Within the framework of construction projects in the UAE, researchers have revealed that change orders, owner-induced delays, as well as planning errors were some of the most prevalent causes of claims [10]. Professionals showed that inexperience of the contractor is usually the main reason behind delays, and a combination of various factors also leads to delays in the project, such as interference by the owners, ineffective decision-making, inadequate planning, and insufficiency of funds to carry out the work [11].

Salama et al. [12] and Abdel-Khalek et al. [13] found that complete contract documentation is to be made, and any discrepancy or error in the contract documents, drawings, and specifications should be identified and resolved as soon as they are detected [14]. Some work in Egypt has looked into the reasons behind claims. Marzouk et al. [15] used literature and interviews to look into the causes of disputes that affect the DRS (Dispute Resolution Strategy) choice. In these studies, a computer-based model was presented, which is a simple yet effective tool that helps stakeholders to choose the most relevant strategy to resolve disputes. A questionnaire had been structured to determine some of the problems witnessed during the process of building management. The findings revealed that claims management of Egyptian industrial construction projects is especially difficult because of a number of factors, such as the absence of appropriate notification procedures and poor document management. It is also important to note that almost 76 percent of the change orders that were observed in the sample were made orally, and almost half of the change orders (made orally) led to a loss of contractual rights because the change orders were not properly documented. Besides, 67 percent of the respondents indicated that the addition of extra work was the principal cause of change orders. This problem is common, as the construction industry in the region is dynamic and fast-moving [16].

Another research indicated that it was found that about 80 percent of construction claims are divided into three major groups. These are delays in issuance of instructions, approval of shop drawings, and project-related decisions (representing approximately 8% of claims); shortcomings in design quality, drawings, and specifications (representing approximately 21%); and alterations made by the use of the owner or consultant, which account for almost half of all claims (approximately 50%) [17]. Other ways to settle disagreements include negotiation, arbitration, mediation, adjudication, and the involvement of dispute review boards. Taking all of these things into account, project leaders can find ways to avoid and lessen disagreements by figuring out the main reasons why they happen [18].

2.1.2. BIM's Effect on Construction Claims and Conflicts

A recent study has analyzed the application of Building Information Modeling (BIM) in the reduction and prevention of various cases of construction claims through the use of a questionnaire survey study [19]. In support of this perspective, the importance of BIM implementation to enhance the faster execution of the construction process, reduce costs, and avoid the possibility of construction claims was emphasized by Rajendran et al. [20]. From the above analysis, it may be emphasized that the increasing sophistication of the electronic, visual, and evidential aspects within the management of construction claims would facilitate the development of BIM within the construction sector.

In cases where BIM is utilized at the initial phases of a project, and the suggested record-keeping process is adhered to, all the project data may be stored in a centralized database connected with a 3D model. This allows claims to be identified, measured, and visualized accurately [21]. Though BIM is mainly designed to improve communication at the stage of design, its usefulness continues through the whole life cycle of the project, and, therefore, BIM serves as a strategic tool to manage and solve claims and, thus, prevent conflicts. The other work was on the development of a BIM-Based Claims Management System (BIM-CMS) to process Extension of Time (EOT) claims with the use of BIM technology. An EOT claims manager was developed as a special plugin under Autodesk Revit by use of Application Programming Interface (API).

The newly developed software was reviewed by experts, and they found that the BIM-CMS could serve to overcome the majority of detected issues and avoid conflicts between project stakeholders in a proficient way [22, 23]. Moreover, studies have shown that BIM may remove eight key causes of claims, such as inaccurate amounts, change orders that are too numerous, design mistakes and revisions, imperfect specification files, and a lack of coordination between structural designers, architectural designers, and MEP designers. This is done by using the capabilities of BIM in visualizing in 3D, detecting clashes, coordinating, and quantity take-offs. Findings of a real-life situation study show that implementation of BIM at the design stage could prevent claims at the construction phase by 55.2%, implying that the capabilities of the technology are useful in mitigating major sources of conflict in the construction industry [24].

2.2. Risks in Construction Projects

The risks of construction projects have been examined in many studies, with a major focus on how broad the location of projects, the type of project, and the research methodology used to glean information differ significantly. On the same note, Bahamid et al. [25]: introduced a detailed list of different risk factors that influence construction projects, with particular attention paid to their influence on project performance. has pointed out a number of key issues. These were a lack of proper coordination and communication among project participants, payment delays, inadequate planning and scheduling, low labor productivity, increasing material costs, and site management.

Sha'ar et al. [26] conducted a study to find out the risks of design-related, wherein a total of critical problems of construction projects were identified. These were variable client needs, poor cross-disciplinary coordination, the inclination to award contracts to the lowest bidder regardless of the quality of the work, the inadequacy of qualified and experienced staff at design firms and on the building site, payment delays, the lack of a special team of quality controllers, and a lack of professionalism. Also, risks associated with clients were noted, and they include financial issues, lack of design documentation, excessive alteration of rules and codes, accidents at the project sites, incompetence, numerous redesigns, the use of unqualified workers, poor organizational culture, and poor use of contracts. Thomas & Sudhakumar [27] conducted an extensive literature review, identifying 173 distinct causes of cost overruns across seventeen diverse project contexts.

2.2.1. Applications of BIM in Risk Management

Particular research observed that BIM can be utilized to generate core data and a platform for additional risk analysis using various BIM-related technologies, including knowledge-based systems, automated rule checking, and proactive and reactive IT-based safety systems. The majority of these technologies could be combined in BIM-related research. Research examined and came up with a BIM-oriented framework that is particularly aimed at risk management in the scheduling of construction projects. This framework has the potential to aid in risk management of projects that deploy 4D and 5D BIM software systems that have integrated risk management modules despite the fact that it was first created based on methodologies of Synchro and Vico, two of the most well-known 4D/5D BIM platforms [28]. Later studies show that the combination of BIM and risk management tools improves monitoring and control of the individual risks associated with a project, which gives a more systematic view of risk management [29].

The results of the surveys show that BIM is also competent in reducing risks at the design and implementation phase, as well as being a platform for documenting risk-related information and sharing knowledge and experience among the project participants [30].Besides, the planning of a project with the help of BIM makes it possible to track the costs of the project and the flow of money, which contributes to the completion of the project cycles on time. The researchers used structural equation modeling (SEM) and exploratory factor analysis (EFA) to determine major barriers using survey data collected through field workers. The research discovered knowledge gaps, insufficient creativity, technical issues, insufficient supervision, and limited functionality to be the key barriers to population-wide use of BIM as a safety management tool [31].

2.3. Labor Productivity in Projects of Construction

Implement Building Information Modeling (BIM), despite the clear evidence of its efficacy in enhancing the performance and efficiency of construction projects. This has, however, been shown to be critical in enhancing labor productivity as BIM has the ability to enhance coordination of project teams. Automated quantity take-offs, clash detection, and real-time monitoring of construction progress allow planning and implementing the construction work more accurately, reducing the number of errors and minimizing delays. It can thus be concluded that the incorporation of BIM in project management processes is highly advisable as a strategic measure to increase the efficiency of the workforce, resolve productivity bottlenecks, and maximize general project performance in the construction sector.

2.3.1. Critical Factors Affecting Labor Productivity in Construction Projects

This study objective based on finding the most important factors that affect labor productivity in building projects from the point of view of project managers [32]. In the identified crucial factors, the analysis reveals the most critical factors influencing the productivity of construction workers are actually ‘ability of construction management,’ 'lack of supervision,’ ‘accident,’ ‘financial status of stakeholders,’ ‘work discipline,’ ‘design changes,’ ‘timeliness of remuneration,’ ‘economic conditions,’ ‘availability of labors,’ and ‘availability of materials." It has been found by many researchers [33, 34], that work area congestion and overcrowding are some of the main things that hurt worker productivity. Additionally, Zhao and Dungan said that congestion is one of the most common ways to measure loss of output. In the construction business, worker morale and attitude are also important factors that affect how much work gets done [35].

On the other hand, Rivas et al. [36], who studied the key aspects affecting the labor productivity of construction workers, reported that the size and dispersion of the tasks are among the most crucial aspects affecting the construction workers’ productivity. In fact, the literature shows that the scattered nature of the work used in the building sector exerts additional pressure on the workers of the construction sector, keeping the sector less productive [37]. In fact, there are indications that workers are less productive at their jobs if the job becomes unnecessarily complicated, as well as if the size of the tasks for the workers are small. Since the size of the other tasks within the construction sector varies, measuring the workers’ productivity within the sector may be practically hard [38]. Because of this, the complexity of the job is seen as one of the main things that affects how productive the construction workforce is [39].

Studies that looked at the things that had the biggest effect on worker productivity found that not having enough supervision was one of them [40]. Ibbs & Sun [35] said that less supervision is a risk that lowers the productivity of building workers. Errors and omissions are another thing that affects the productivity of building workers [36]. Usually, mistakes and errors are closely linked to rework, since bad work needs to be redone to reach or meet the quality standards. Because of this, rework is seen as one of the main things that lowers the productivity of building workers [41]. Literature also shows that site logistics has a big effect on how much work gets done in buildings. In fact, construction workers say that problems with materials and tools are mostly caused by a lack of good logistics on the job site or in the field [36].

Thomas & Sudhakumar [27] created models to analyze the many factors that determine work output, but discovered that too much overtime is one of the most serious factors that negatively impact productivity. Besides the working hours, environmental factors, especially weather, contribute significantly to productivity at construction sites. The effect of extreme temperatures, either too hot or too cold, has also been observed to be directly related to the rate and performance of construction operations [35]. Another common challenge that Hasan et al. [42] found to be the main hindrance to worker productivity in the construction sector is the adverse weather conditions.

The workforce may become inefficient either during periods of excessive workforce or during periods of insufficient workforce, and in either case, it is also known as crew size waste [35]. Moreover, the productivity of workers is greatly affected by specific conditions of the site and the operational needs. Accessibility, terrain, and site layout are often described as one of the key stressors of field efficiency [43]. Lastly, proper work scheduling plans are also known to be important construction management strategies that may be related to maximizing the efficiency of labor, the allocation of resources, and improving the productivity of the whole project. Such measures, together with the appropriate planning and control, will play a significant role in alleviating losses in productivity and meeting project deadlines [44].

Moreover, a number of researchers have pointed out that out-of-sequence work may cause disruption to the working process, making employees change their standard procedures and cooperate with other teams, so it may lead to decreased productivity [33]. A study conducted by El-Batreek et al. [45] has highlighted the need to have a good working relationship among various trades as the only way of ensuring a high level of productivity. Indeed, lack of coordination and proper communication is reported consistently in the literature as being the key factor that inhibits construction workforce performance [43].

2.3.2. Impact of BIM on Labor Productivity

Over the last few decades, more studies have tried to figure out how much BIM affects construction productivity. As an example, Coates et al. [46] looked into how to measure labor efficiency for structural formwork using BIM. They found that monitoring and controlling the progress of building is the best way to get information about productivity. Also, they talked about how 3D BIM modelling and amount take-off could help with figuring out how productive something is. They did not, however, look into how BIM might affect productivity, which is what makes these changes possible. Also, more recent studies have tried to figure out how much BIM affects the output of workers. A study carried out by Bryde et al. [47] examined the effect of Building Information Modeling (BIM) on six key performance indicators in the construction field, which included safety (including lost man-hours), project cost, quality control (including rework), units produced per labor hour, and cost per unit performed.

The authors also found that total man-hours spent, project progress rate, and the revenue obtained per person were the most important KPIs in determining the effectiveness of BIM in a project-based scenario. In another study, a structured, closed-ended, quantitative questionnaire was used whereby leading construction firms with experience in BIM implementation were given the questionnaire. This survey examined the effects of BIM on three levels, namely, project, organizational, and individual. The findings showed that BIM variables regarding personal oversight were the factors with the strongest positive influence on labor productivity. Therefore, the research suggested the incorporation of BIM under the individual (supervision) category to be a strategy of improving low construction output [48]. In addition, another paper was focused on the analysis of the ongoing reduction and stagnation of labor productivity in the construction sector. Specifically, this paper emphasized the point that the effectiveness of the labor force might be greatly influenced by BIM, taking into consideration the fact that the cost of the labor force generally comprises between 20 and 50 percent of the entire cost incurred during the construction process [49].

2.4. Research Conceptual Framework

The effective and widespread use of Building Information Modeling in the construction sector requires the development of effective implementation guidelines. In fact, the inclusion of various stakeholders in the development of such guidelines assumes key significance, as such an approach ensures the effective uptake of the guidelines at the industrial level. The development of such guidelines should play an integral role in ensuring the mitigation of risks and dispute issues in the sector, thus contributing to superior performance levels in projects. In response to the key research requirements and the identified deficiencies in existing literature on the subject, the proposed study focuses on the development of an innovative management approach and checklist based on the empirical analysis of projects enabled by Building Information Modeling techniques to effectively prevent the escalation of claims into dispute situations and enhance labor productivity in the construction sector.

Figure 1 shows the conceptual framework of BIM-based claims, risk, and productivity management that will be followed in this research to analyze and integrate BIM in my project.

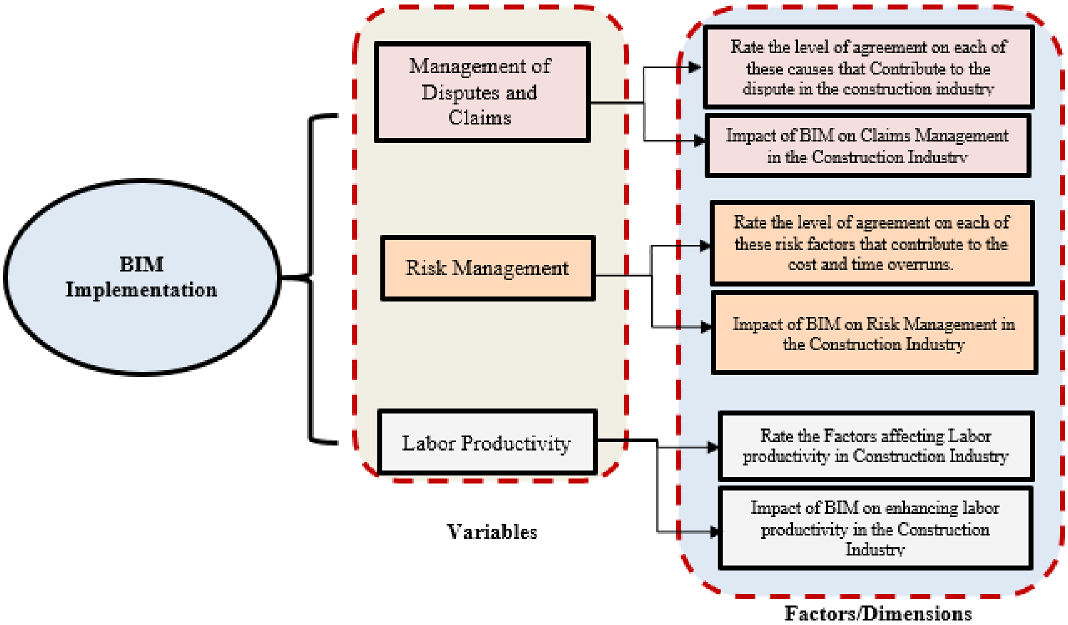

Figure 1. Conceptual Framework

3. Methodology

The framework of research design includes the selection of study components and design attributes by the researcher. The primary elements of study design comprise the sampling strategy, research instruments, methodological approach, and statistical methods, organized into five distinct phases: problem identification, literature review, development and distribution of questionnaires, data analysis, and the integration of case studies. This study design is both descriptive and exploratory, as shown in Figure 2, applying a mixed-methods approach to explore the effects of BIM implementation on construction projects by combining quantitative and qualitative data through opinion questionnaires from construction stakeholders. The questionnaire will consist of closed-ended demographic questions and specific study topics, along with a Likert scale to measure responses.

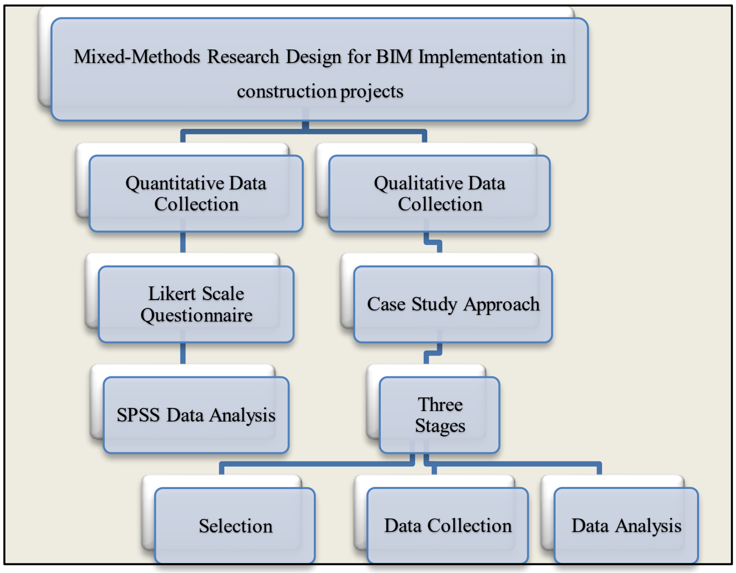

Figure 2. Research Methodology

3.1. Data Collection Tools

A variety of data sources were used during the study's research. The current study's theoretical and applied elements are built upon one another. Theoretically, for the current investigation, the researcher drew from pertinent scientific studies. On the practical side, data are gathered, assessed, and hypotheses tested using a descriptive and analytical technique. On the practical side, a descriptive and analytical approach is used to gather data, analyse it, and test hypotheses. There are two categories of data collection techniques:

- Primary source: A questionnaire was created specifically to gather primary information about all the research variables and the demographics of the research sample in accordance with the research objectives and previous empirical studies.
- Secondary source: The study's theoretical framework, model, and assumptions were developed using books, journals, and theses for developing the case study and the literature review.

3.2. Study Population and Sampling

- The target sample in this study comprises the individuals who work in several capacities for companies that have already utilized BIM. In selecting the respondents, a variety of business entities will be used, such as main contractors and subcontractors, consultants, and clients.
- The non-probability sampling methodology will be used to obtain the sample, where convenience sampling will be applied to select those who can easily be accessed and are willing to participate in the study. The population target for this research study is construction professionals with BIM competency working in Egypt, Saudi Arabia, and Qatar.
- Sampling will be carried out by BIM experts who are engaged within the construction sector from selected nations. The size of the sample could vary from a minimum of 100 to a maximum of 120 participants for the study. This remains valid for the purpose of providing credible information that validates statistics.

In the proposed study, convenience sampling was used based on the limitations of reaching the participants directly, who are the entire group of professionals involved in BIM-related projects in the Egyptian constructed environment. The sampling technique takes less time and costs fewer resources, though both may be subject to certain biases, and the results might not be entirely representative for the sector at large. Findings are the opinions of the sample group. A sample size of 120 valid responses was collected, which could be used for statistics such as correlation and Structural Equation Modeling (SEM), especially for models of equal complexity mentioned above; this follows Hair et al.'s recommendation [50].

3.3. Data Analysis

Data analysis refers to the systematic process of investigating, refining, modeling, and purifying data in order to identify key insights, draw valid conclusions, and support informed decision-making. It concerns a very broad process, which encompasses a number of methods and techniques in a vast array of subject matters and areas, having very diverse terminology and processes according to the discipline. The Statistical Package for the Social Sciences (SPSS) refers to very general-purpose computer-based software designed specifically for the support of data entry, processing, and generation of tables and graphics. With the support of SPSS, the researcher can utilize descriptive statistics as a means to summarize the features of the data, for example, calculation of frequencies, percentages, measures of central tendency, and measures of dispersion.

Finally, after the data has been processed, the findings may be placed in the form of tables and graphics for reporting purposes in documents written using Microsoft Word. Quantitative data that were gathered using questionnaires in this study were analyzed using SPSS. The demographic data and answers to the essential questions were summarized with the use of descriptive statistics that gave a clear picture of the data set. Significant relationships among variables were analyzed using inferential statistical techniques such as chi-square and regression to determine the Building Information Modeling (BIM) effect on project management issues. These methods of analysis allowed the finding of patterns and correlations, which justified evidence-based findings about the efficiency of BIM in reducing project management problems.

4. Questionnaire and Analysis

4.1. Questionnaire Design

The survey questionnaire that will be used in this research will be made up of all closed-ended questions, which will assist in minimizing bias, especially for respondents who are less literate in both self-administered and interviewer-administered questionnaire. Closed-ended questions have a number of benefits: they are fast and simple to respond to, simple to code and record, open to statistical analysis, and can be presented easily in a report. It was based on these factors that only closed-ended questions were used in the questionnaire design. The tool will have two major parts corresponding to certain areas of the research objectives. One hundred and twenty (120) questionnaires had been completed in full and a valid response rate of 120 was obtained, which will provide strong and robust data to be used in future analysis.

4.1.1. Section One: Demographic Variables

The demographic information was gathered using closed-ended questions and seven different characteristics, including gender, age, Position, Experience in the Construction Sector, Education Level, construction party, and Company BIM Implementation.

4.1.2. Section Two: This section Investigates Each of the Following:

- Causes of Disputes and Claims in the Construction Industry: Recognizing the key causes of conflicts and claims associated within the construction process.
- Strategies for the Effective Implementation of BIM in Construction Projects: Outlining systematic approaches and best practices for the successful implementation of Building Information Modeling (BIM) in projects within the construction sector.
- BIM's Effect on Claims Administration during Live Projects: Describe the role of BIM in eliminating conflicts and optimizing the process of claim administration during projects that are presently ongoing.
- Risk Factors Affecting the Construction Process: Focus on the internal and external elements impacting the risks, delays, and uncertainties involved in the process.
- Determinants of Labor Productivity in Construction Projects - Exploring the major factors influencing the efficiency and productivity of workers in the construction sector.
- Role of BIM in Improving Risk Management in the Construction Industry: Assessing the role of BIM processes within risk management during the construction phase from beginning to end.
- Impact of BIM on Labor Productivity in the Construction Industry: Exploring the influence of BIM on boosting labor productivity in the construction industry by optimizing workflows and labor coordination.

The process of carrying out the survey was smooth since the questionnaire employed a five-point Likert scale to measure the level of agreement of the participants to the questions, thus making the process of data analysis easier. The participants were required to choose the answer that best indicated their opinion, with the possible variants of Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree. One hundred and twenty valid responses were obtained, which is an adequate sample size in terms of carrying out different statistical tests, such as descriptive statistics, correlation analysis, and structural equation modeling (SEM), at least with moderately complex models. Hair et al. [50] say that a sample size of 100 to 120 respondents is typically enough to conduct SEM-based research, which justifies the reliability and validity of the findings in this study.

4.2. Validity and Reliability

The researchers used the Cronbach alpha test, a well-known statistical measure of internal consistency, which was first developed in the 1940s, to guarantee the reliability and robustness of the questionnaire. Cronbach's alpha coefficients are used to estimate the correlation between the questions asked within a given questionnaire, providing an index of the extent to which the instrument measures the variable in a consistent manner. A high level of Cronbach's alpha indicates the consistency within the questions asked within the instrument, which makes the results from the investigation credible. In addition to the statistical reliability test, a pilot study was carried out among the 15 participants. A pilot study was carried out to analyze the understandability of the questions posed in the survey, relevance, and the general level of understanding of the survey, ensuring that the participants could understand and identify the answers to the questions correctly.

$$\text{Cronbach's alpha } \alpha = (k/(k-1)) \times (1 - (\sum \sigma^2 yi \,/\, \sigma^2 x)) \quad (1)$$

where, k: Represents the total number in the scale or test; $\sigma^2 yi$: Represents the item variance. This is calculated by finding the average squared difference between each item's score and its mean; and $\sigma^2 x$: Represents the variance of the total scores. This is calculated by finding the average squared difference between each total score and the mean of the total scores.

4.3. Face Validity

The questionnaire was assessed for its validity by three experts through hand delivery and email. Based on their feedback, several modifications were made to the questionnaire. Some of these comments are as but not limited to, the following.

- Made corrections to the questionnaire's structure, which asked about the demographic information of the respondents and their work performance style.
- Examined the English words on the questionnaire and suggested a few words, as well as the rating scales that referred to a five-point Likert scale for every field.
- Some questions are very long, and it would be better to be shorter and more specific.
- Some questions are repeated with the same meaning as other questions.

Table 1 briefly outlines the questionnaire, highlighting the five major sections of the questionnaire, as well as the procedures followed to test its validity and reliability. The paper identifies and discusses the key elements that lead to controversial allegations, risks involved, and gains in the project productivity as viewed by all key stakeholders in the construction sector, which comprises the owners, the consultant, and the contractors. These aspects were then given priorities in order of their importance so as to be able to identify the most important aspects that determine the outcome of projects. Besides these insights, the paper also provides a proposed management framework and a full checklist that should be used as practical tools by the construction managers. These tools are designed to avoid escalation of claims to disputes, to reduce project risks, and also to improve labor productivity and general project efficiency.

Table 1. Sampling of the questionnaire, Target Population, and data collection

Section	Details
Questionnaire Description	This study's questionnaire targeted AEC industry professionals to gather insights on issues concerning the effects of BIM on claims management, risk management, and labor productivity in construction projects.
Sample Questions	***Claims Management:*** • Which factors most frequently trigger conflicts and claims in construction projects? • In what ways can BIM adoption enhance the handling and resolution of claims in construction projects? ***Risk Management:*** • Which key risk factors have the greatest influence on construction projects? • How does the integration of BIM improve risk management practices in construction projects? ***Labor Productivity:*** • What are the factors affecting labor productivity in construction projects? • In what way does the implementation of BIM impact labor productivity in construction projects?
Validity and Reliability Checks	***BIM Implementation:*** • What are the various aspects of BIM implementation on construction projects? • Rank the benefits of BIM implementation in your company. ***Face Validity:*** • The questionnaire survey was piloted among three construction management and BIM experts for the purpose of establishing the face validity of the questions. • Comments are included, and questions are modified for clarity and relevance. ***Content Validity:*** • The questions were identified based on a thorough literature review as well as the input of practitioners in the field for content validity for the survey tool. • The questions revolved around the essential themes of the management of claims, risk management, labor productivity, and BIM implementation. ***Reliability*** • Internal consistency of the questionnaire was measured through Cronbach alpha coefficient. • Constructions showed the acceptable level of reliability, and for each of them, the Cronbach alpha exceeded the suggested level of 0.70. ***Sample Size Validity:*** A cross-sectional study sample was used since the study was exploratory, as indicated in a previous study [51]. Beyond the limited resources and time, this study presents the first indications for an understanding of the phenomenon under investigation. • With 120 participants, the sample size was judged to be adequate for conducting factor analysis since it went beyond the recommended lowest requirement of 10 to 15 participants for every item. The sample size was determined based on statistical recommendations for structural modeling and factor analysis, which stipulate that 5–10 participants should be available for each variable, ensuring sufficient analytical power and interpretable results [52].

4.4. Demographic Details of Respondents

Findings from the questionnaire offer some key information on various aspects of the research study. A description of the nature among the participants is identified within Table 2, providing a clear description of the composition within the sample group, identified to be very useful within the context of the paper explaining the BIM impact on the process of project management.

Table 2. Demographic details of respondents

Demographic Aspect	Category	Number of Respondents (120)	Frequency (%)
Gender	Male	106	88.30
	Female	14	11.70
Education Level	High School	06	5.00
	Bachelors	97	80.83
	Masters / PhD	17	14.17
Organization / Company	Main / Sub-Contractor	93	77.50
	Consultant	19	15.80
	Client	7	5.80
	Others	1	0.80
Job Role	Junior Engineer	31	25.80
	Senior Engineer	57	47.50
	Head of Department	23	19.20
	Project Manager	9	7.50
Total Years of Experience	Less than 5 years	30	25.00
	6-10 years	38	31.70
	11-15 years	33	27.50
	More than 15 years	19	15.80
Total Years of BIM Experience	Less than 5 years	80	66.70
	6-10 years	28	23.30
	11-15 years	8	5.80
	More than 15 years	7	4.20

The primary objective of the questionnaire survey revolves around the discussion of the effects of Building Information Modeling (BIM) during the execution of the construction projects, particularly concerning the mitigation of risks and claims and the enhancement of labor productivity.

The results of the questionnaire survey also identified critical problems existing in the construction sector, which affect projects negatively, such as the improper management of time and a lack of communication, which have been identified as the most critical causes of conflicts and claims. Furthermore, the paper has emphasized the critical importance of BIM in the improvement of risk management processes as well as the productivity of the workforce. The results identified the importance of the development of personalized approaches for the implementation of BIM within the construction sector to prove the effectiveness of BIM as a valid method for the effective management of the performance of projects, the mitigation of conflicts, and the effective management of the workforce.

4.5. Quantitative Data Analysis

4.5.1. Measurements

The data analysis was carried out using IBM's SPSS Statistics (Statistical Package for the Social Sciences). The analysis used the following quantitative measures.

4.5.2. Descriptive Statistics

Central Tendency (Mean):

- Dispersion:

It is important to note that the mean and standard deviation are measurements of dispersion. The standard deviation and the mean of answers were used to measure statistical dispersion. This method would enable us to comprehend the variability in perceptions of the participants and how much respondents are clustered around the average, which would give us an idea of whether the respondents are in agreement or not.

- Relative Importance Index [RII]:

It was used to arrange the items or variables covered in Sections 2, 3, 4, and 5 of the questionnaires in order of how the respondents perceive them. This approach measures the relative weight of all the factors, which allows for determining the most important factors influencing construction claims, risks, and labor productivity. Other statistical methods such as factor analysis, regression analysis, and paired comparisons, were carried out to confirm the associations between variables and also to establish underlying patterns.

- Structural Equation Modeling (SEM):

These Equations have been used in survey research, business intelligence, engineering, and scientific studies because it provides a robust framework for understanding complex relationships. In this context, these equations have been used to test the connections between observed and underlying variables. Structural equation modeling is used in various applications. Not only does it provide a descriptive summary of the association between two variables, but it is also easier to analyze direct and indirect relationships and clarify the causal relationships and how a variable affects another within the context of BIM adoption, claims management, risk mitigation, and labor productivity.

4.5.3. Validity of Sample Size

- The sample size affects how reliable factor analysis is. A sample with more than 50 respondents but fewer than 100 respondents can be used for PCA.
- It is generally recommended that the sample size includes a minimum of 10 to 15 responders for each item or variable.
- That is, the sample size recommended must be no less than ten times that of the number of items or variables in the study, with some researchers indicating even a more conservative estimate of twenty times as the guarantee of statistical reliability and robustness.

4.5.4. Causes of Claims in the Construction Industry

The descriptive statistics presented below; including Mean, Standard Deviation, Standard Error, and IRR Ranking; illustrate respondents' evaluations and rankings of the variables and their associated issues that contribute to claims in the construction industry, based on the highest and lowest mean values and the overall trends observed for each factor. Table 3 summarizes the variables relevant to the study of claim causes along with their related factors, followed by the detailed descriptive statistics.

- The management-related issues present that poor communication is the most critical management issue.
- The financial-related issue presents that payment issues are the most critical financial issue, ranking first, affecting project stability and stakeholder satisfaction.
- The construction-related issues that present delay issues emerged as the most significant construction-related concern (Ranking 01 with the highest means & standard deviations). This indicates that project delays are a critical concern among respondents, significantly impacting project timelines and overall efficiency.
- The Contract issues breaches of Contracts emerged as the most significant contract-related concern, which indicates that breaches of contract are a critical concern among respondents, significantly impacting project integrity and stakeholder trust.

Table 3. Disputes and claims related to issues with their associated factors

Management Related Issues	Mean	Std. Deviation	Std. Error	Rank
[Poor Communication]	4.18	1.137	0.104	1
[Poor Time Management]	4.16	1.115	0.102	2
[Poor Cost Management]	4.14	1.095	0.09	3
[Poor Quality Management]	3.87	1.004	0.092	4
[Poor Site Management]	3.61	0.99	0.1	5
Financial Related Issues	**Mean**	**Std. Deviation**	**Std. Error**	**Rank**
[Payment issues.]	4.15	1.105	0.101	1
[Finance issues.]	3.84	0.97	0.089	2
[Changes in the Economic Situation.]	3.94	1.071	0.098	3

Construction-related issue	Mean	Std. Deviation	Std. Error	Rank
[Delay issues.]	4.27	1.01	0.092	1
[Work Change Orders.]	4.26	0.884	0.081	2
[Incomplete Information.]	4.01	0.865	0.079	3
[Failure in Sublet of Contract.]	4	1.004	0.092	4
[Lack of Experience.]	3.93	0.89	0.081	5
[Adversarial Relationship between Contractors]	3.81	0.853	0.078	6
[Unforeseen Site Condition.]	3.7	0.826	0.075	7
[Unable to Perform Task.]	3.39	0.964	0.088	8
[Inclement Weather.]	3.33	0.801	0.073	9
[Unrealistic Expectations.]	2.75	1.252	0.114	10
Contract Related Issues	**Mean**	**Std. Deviation**	**Std. Error**	**Rank**
[Breaches of Contracts.]	4.18	0.941	0.086	1
[Disagreement on Claims.]	4.16	0.987	0.09	2
[Poorly Written Contracts.]	3.93	0.837	0.076	3
[Different Interpretations of the Contract Provisions]	3.66	0.855	0.078	4
[Ambiguous Contract Languages]	3.51	1.145	0.105	5
[Unrealistic Tender Pricing.]	2.98	1.134	0.103	6
[Unfair Risk Allocation.]	2.88	1.017	0.093	7

4.5.5. Impact of BIM on Claims Management in the Construction Industry

Table 4 shows the descriptive statistics connected to the effects of Building Information Modeling (BIM) on the management of claims in the construction sector. The table draws the attention to the variables that have the highest and the lowest mean scores, which gives an idea about which factors are most and the least considered by the respondents to be influential. Moreover, it presents general tendencies in the data, which makes it possible to better understand the contribution of BIM to the minimization of claims and conflicts and improvements in project management practices.

Table 4. The Impact of BIM on Claims Management in the Construction Industry

Statement	Mean	Std. Deviation	Std. Error	Rank
Use of visualization techniques minimizes the risk of change orders	4.28	0.927	0.08	1
Visualization aids in limiting the ex-gratia claims from the contractors for underestimating the material quantities/costs.	4.35	0.866	0.079	2
Changes in the design or specifications because of errors are addressed by the coordination and clash functions of the 3D coordination and management process.	4.33	0.947	0.086	3
Variations in the interpretation of contract provisions	3.63	1.045	0.095	4
Leverage optimized workflows so that the process of communication avoids problems such as information clarity, content, and timeliness.	4.06	0.843	0.077	5
BIM-enabled e-procurement systems minimize cost uncertainties and ambiguities in contracts.	3.05	1.511	0.138	6
Prefabrication results in less rework and fewer change orders.	4.07	0.742	0.068	7
Prefabrication helps to avoid claims for delays.	3.98	0.809	0.074	8
BIM's geospatial solutions result in a reduction of claims for differing site conditions, unexpected changes, and delays.	3.95	0.765	0.07	9

- The survey reveals that BIM visualization significantly reduces ex gratia claims and minimizes change orders, reducing project delays and costs.
- However, it also has moderate confidence in reducing cost uncertainties and delays through prefabrication and e-procurement.
- The lowest-rated factors are BIM-based E-procurement, which reduces cost uncertainty and contract ambiguity.
- Overall, BIM's role in claims management is positive, emphasizing the importance of visual and coordination tools.
- These results, aimed at effectively managing claims in the construction industry, demonstrate the importance of visual and coordination tools in BIM.

4.5.6. Causes of Risks in the Construction Industry

Table 5 shows descriptive statistics showing the respondents' evaluation and ranking of the variables and their related issues, which are causing risks in the construction industry, based on the highest and lowest mean values and the overall trends for each factor-related issues. Table 5 shows the variables relevant to the analysis of the causes of risk, as well as the associated factors. The descriptive statistics for the above results are as follows:

- Regarding the issues of the Planning & Controls, the data from the descriptive statistics reveals the importance of BIM in planning and control processes within construction projects, in addition to the points needing enhancement.
- Regarding execution-related issues, the results from the descriptive statistics analysis of the data show delays in approval and changes occurring during construction are the most serious execution problems, whereas problems associated with construction techniques and submittals are less serious.
- Issues relating to regulations, the data from descriptive statistics indicates that changes in regulations are the most crucial regulatory issues, compared to the level of political opposition and administrative complexity.
- Project Finance Related issues, the descriptive statistics data highlights the significance of the process of payment certifications in the context of management of project finance, specifically in the context of the construction sector.
- Unforeseen issues and communication-related problems, the data for descriptive statistics highlights the significance of effective communication and clear design requirements in managing risk and improving the performance of projects in the sector of construction. The focusing aim on communication issues and optimizing design requirements should be emphasized to ensure the smooth operation of projects.
- Resource-related issues: the descriptive statistics for resource-related issues in the context of construction projects bring to the fore the importance of resource management in the workforce and equipment for optimized results in the construction sector.

Table 5. Risk-related issues with their associated factors

1- Planning & Controls Related Issues	Mean	Std. Deviation	Std. Error	Rank
[Inadequate planning—poor site management]	4.35	0.866	0.079	1
[Public utilities such as electricity and water were difficult to access]	4.2	0.931	0.085	2
[Prior to construction, site inspections were not thorough]	4.18	0.898	0.082	3
[Delay in delivery of materials.]	3.99	0.884	0.081	4
[Delay in obtaining permits and licenses.]	3.94	0.946	0.086	5
[Unrealistic estimated duration for project activities/phases]	3.81	1.095	0.1	6
2- Execution	**Mean**	**Std. Deviation**	**Std. Error**	**Rank**
[Delay in approving design documents]	4.31	0.924	0.084	1
[Alteration of material specifications during the construction phase]	4.3	0.913	0.083	2
[Changing of scope]	4.25	1.031	0.094	3
[Excluding final tests, delays during project inspections and testing]	4	0.733	0.067	4
[Delays in final inspections]	3.82	0.84	0.077	5
[Inappropriate construction methods]	3.72	0.758	0.069	6
[Poor quality bids submitted by contractors]	3.56	0.924	0.084	7
3- Regulation-related issue	**Mean**	**Std. Deviation**	**Std. Error**	**Rank**
[Frequent changes in legislation, particularly those governing the import and export of construction materials, can significantly affect project planning, procurement processes, and overall construction timelines.]	3.94	0.802	0.073	1
[Changing government regulations]	3.9	0.844	0.077	2
[Currency exchange rate]	3.08	1.131	0.103	3
[Complicated administration process]	3.01	1.177	0.107	4
[Strong political opposition/hostility.]	2.9	1.126	0.103	5
4- Project Finance	**Mean**	**Std. Deviation**	**Std. Error**	**Rank**
[The contractor payments certification delaying]	4.34	0.884	0.081	1
[The 2 payments certification delaying]	4.22	0.936	0.085	2
[Material price fluctuations.]	3.2	1.127	0.103	3
[Funding problems from contractors.]	3.18	1.142	0.104	4
[Delay in paying staff salaries.]	3.04	1.103	0.101	5

5- Unforeseen Conditions and Communication	Mean	Std. Deviation	Std. Error	Rank
[Poor communication between 3s, 2s, and contractors]	4.15	1.01	0.092	1
[Lack of design requirements.]	4.13	0.943	0.086	2
[Misunderstanding of authorities' requirements]	3.88	1.05	0.096	3
[Labor unrest/strikes]	3.73	0.978	0.089	4
[Bad weather]	3.7	0.975	0.089	5
[Unexpected situations related to HSE issues, natural hazards, or labor-related disruptions]	3.28	1.109	0.101	6
6- Resources	**Mean**	**Std. Deviation**	**Std. Error**	**Rank**
[Availability of skilled labor]	4.16	0.85	0.078	1
[Availability of equipment]	4.02	0.917	0.084	2
[Shortage of construction materials in the market]	3.99	0.772	0.071	3
[Capability of subcontractors/suppliers]	3.89	0.848	0.077	4
[Possibility of maintaining equipment easily]	3.45	0.96	0.088	5

4.5.7. Impact of BIM on Risk Management in the Construction Industry

In Table 6, the description statistics for the impact of BIM on risk management within the construction sector are exemplified, portraying the influence of BIM on improving risk management processes through the collaborative decision-making process, clash results, and multidisciplinary knowledge.

Table 6. The Impact of BIM on Risk Management in the Construction Industry

Statement	Mean	Std. Deviation	Std. Error	Rank
Collaborative decision-making among stakeholders through BIM reduces risks during the design phase.	4.44	0.797	0.073	1
BIM's clash detection capabilities minimize risks encountered during construction and implementation.	4.43	0.817	0.075	2
By integrating multidisciplinary expertise, BIM supports the development of more effective strategies for mitigating design and construction risks.	4.38	0.871	0.080	3
The shared BIM environment enhances communication and collaboration, reducing risks associated with poor coordination among project parties.	4.38	0.889	0.081	4
BIM should maintain a database of risks and lessons learned throughout the risk management process.	4.34	0.783	0.071	5
Using BIM to align design with project scope and budget reduces overall project uncertainty.	4.33	0.842	0.077	6
The visualization of risks across project phases through BIM supports effective assessment and mitigation throughout the project lifecycle.	4.33	0.862	0.079	7
The 5D BIM model (3D + cost + schedule) enables proactive tracking and mitigation of project risks.	4.32	0.907	0.083	8
BIM's ability to integrate external project conditions with risk elements enhances risk assessment.	4.30	0.816	0.074	9
BIM-based tools facilitate quality control by identifying and monitoring risks related to poor workmanship.	4.27	0.786	0.072	10
BIM supports early identification and mitigation of risks during the project's design stage.	4.25	0.781	0.071	11
Interoperability through IFC standards and knowledge-sharing platforms promotes effective risk management.	4.25	0.812	0.074	12
BIM allows clients to monitor project progress by identifying and mitigating emerging risks.	4.23	0.761	0.069	13
BIM ensures consistent monitoring and reporting of the risk management process.	4.20	0.784	0.072	14
Ineffective implementation of BIM may introduce secondary risks, potentially increasing overall project risk levels.	4.18	0.796	0.073	15
Automated rule-checking features in BIM reduce the likelihood of design errors.	4.17	0.863	0.079	16
Regular revision control within a shared BIM platform supports efficient change management.	4.13	0.751	0.069	17
Knowledge and experience stored in BIM contribute to learning-oriented risk management.	4.11	0.838	0.077	18
BIM's parametric modeling facilitates easy model updates, aiding in risk identification, monitoring, and revision.	4.11	0.742	0.068	19
BIM supports the transfer of risk-related knowledge and lessons learned from previous projects to future ones.	4.00	0.733	0.067	20
By enabling information sharing among stakeholders, BIM enhances overall awareness of potential risk sources.	3.99	0.921	0.084	21
BIM's spatial and locational data capabilities help identify and reduce construction-related risks.	3.95	0.754	0.069	22
Early-stage safety planning using BIM can significantly reduce safety-related risks.	3.90	0.782	0.071	23

- The subject of the survey involves the effect Building Information Modeling (BIM) has on risk management within the construction sector. The survey identifies certain aspects where BIM might have limitations or difficulties. For example, although BIM could facilitate the sharing of risk information among stakeholders, there might be difficulties in the sharing process, thus influencing risk awareness and management.

- It also highlights the fact that BIM facilitates a collaborative process of decision-making for stakeholders, especially during the design stage, thus minimizing risks. Furthermore, the process of Clash Detection in BIM makes it possible to resolve conflicts related to construction upfront, thus minimizing risks during the execution phase.
- These elements indicate a positive consideration of the role BIM provides in improving risk management functions through collaboration, carrying out clash detection, and the integration of diverse knowledge domains. Yet, there could be difficulties in leveraging the spatial risk information the BIM process provides.

4.5.8. Causes Affecting Labor Productivity/Performance in the Construction Industry

From Table 7, it can be seen that the description of the statistics for the factors of labor productivity and performance in the construction sector comprises key information about the management of the workforce in the sector, taking both the positive and negative aspects into consideration. The information presents the importance of advocating for the optimal utilization of the capacities of the workforce in the construction sector, notwithstanding the related challenges such as the impact of absenteeism and personal problems, among others.

Table 7. Labor Productivity / Performance issues with their associated factors

1- Manpower Factors	Mean	Std. Deviation	Std. Error	Rank
[Labor's Experience and Skills.]	4.24	0.778	0.071	1
Factors [Absenteeism.]	4.2	0.984	0.09	2
Factors [Work discipline.]	4.15	0.827	0.075	3
Factors [Age of Labor]	4.13	0.894	0.082	4
Factors [Strength and Physical of labor.]	4.06	0.833	0.076	5
Factors [Labor Education Level.]	3.48	0.721	0.066	6
Factors [Personal Problems]	3.15	0.976	0.089	7
2- Management	**Mean**	**Std. Deviation**	**Std. Error**	**Rank**
[Availability of materials.]	4.45	0.743	0.068	1
[Communication.]	4.43	0.837	0.076	2
[Lack of supervision.]	4.37	0.819	0.075	3
[Lack of Supervision's Experience.]	4.36	0.877	0.08	4
[Re-work.]	4.34	0.865	0.079	5
[Working Overtime.]	4.28	0.86	0.078	6
[Availability of labors.]	4.11	0.683	0.062	7
[Construction Methods.]	3.99	0.704	0.064	8
[Site Management.]	3.99	0.68	0.062	9
[Availability of Equipment /Tools.]	3.98	0.661	0.06	10
[On-site Storage.]	3.83	0.771	0.07	11
[Ability of Construction Management.]	3.78	0.874	0.08	12
[Financial Status of stakeholders.]	3.53	1.092	0.1	13
3- Motivation Factors	**Mean**	**Std. Deviation**	**Std. Error**	**Rank**
[Motivation of labors.]	4.34	0.865	0.079	1
[Rewards/Punishments.]	4.25	0.928	0.085	2
[Lack of labor recognition programs.]	4.24	0.961	0.088	3
[Amount of remuneration.]	3.98	0.825	0.075	4
[Timeliness of remuneration.]	3.97	0.697	0.064	5
[Creating competition.]	3.87	0.809	0.074	6
[Work Satisfaction.]	3.83	0.823	0.075	7
[Promote opportunities.]	3.81	0.843	0.077	8
4- Work Condition Factors	**Mean**	**Std. Deviation**	**Std. Error**	**Rank**
[Working Space.]	4.31	0.807	0.074	1
[Work security.]	4.18	0.869	0.079	2
[Healthy and Safety Conditions.]	4.07	0.837	0.076	3
[Height of Worksite.]	3.99	0.825	0.075	4
[Accident.]	3.61	0.813	0.074	5

5- Project Factors	Mean	Std. Deviation	Std. Error	Rank
[Project type.]	4.25	0.91	0.083	1
[Design complexity.]	4.13	0.773	0.071	2
[Drawing quality.]	4.12	0.78	0.071	3
[Design changes.]	4.11	0.754	0.069	4
[Sub-contractor.]	4.11	0.838	0.077	5
[Project location.]	3.79	0.755	0.069	6
[Effective project.]	3.56	0.731	0.067	7
6-External Factors	**Mean**	**Std. Deviation**	**Std. Error**	**Rank**
[Weather conditions.]	3.99	0.855	0.078	1
[Regulation and law.]	3.93	0.786	0.072	2
[Geological and hydrological conditions.]	3.93	0.769	0.07	3
[Economic conditions.]	3.74	0.704	0.064	4
[Social culture.]	2.89	1.187	0.108	5

4.5.8. Impact of BIM on Enhancing Labor Productivity in the Construction Industry

Table 8, presenting the descriptive statistics, indicates that using BIM technology significantly reduces issues related to coordination among different trades and activities on the construction site. By facilitating precise visualization and coordination within the virtual environment preceding the actual construction work, BIM ensures easier workflows, fewer clashes, and effective resource allocation. With enhanced coordination achieved, the overall labor productivity gets improved since coordination conflicts cause downtime and rework.

Table 8. Impact of BIM on Enhancing Labor Productivity in the Construction Industry

Impact of BIM on Enhancing Labor Productivity in the Construction Industry	Mean	Std. Deviation	Std. Error	Rank
[BIM decreases the number of field coordination problems.]	4.43	0.785	0.072	1
[BIM helps in monitoring the performance of the complex project with a tight schedule.]	4.4	0.854	0.078	2
[BIM aids in decreasing the project cost.]	4.37	0.819	0.075	3
[BIM achieves improved safety performance in the building post-occupancy phase.]	4.33	0.892	0.081	4
[BIM guarantees a safer construction process.]	4.32	0.86	0.078	5
[BIM helps in having a faster regulatory approval.]	4.31	0.868	0.079	6
[While using BIM, less field coordination would be required on site.]	4.31	0.868	0.079	7
[BIM designs make the on-site team focus on the construction process and sequencing of work, instead of managing the materials and tools in the field.]	4.28	0.918	0.084	8
[BIM reduced the site activity.]	4.16	1.1	0.1	9

4.5.9. Implementation of BIM

From Table 9, BIM enables the sharing of information and models on a real-time basis, thus providing an effective means for communication and coordination between the architect, engineer, contractor, and other stakeholders of a given project. Improved collaboration results in effective decision-making, fewer errors, and optimized results for the projects.

Table 9. BIM Implementation

BIM Implementation	Mean	Std. Deviation	Std. Error	Rank
"Integration of BIM increases the quality of project programming and construction schedules."	4.3	0.81581	0.07447	1
"BIM implementation encourages interdisciplinary collaboration and communication."	4.2667	0.88625	0.0809	2
"Using BIM enhances cost estimation and management during projects."	4.25	0.90051	0.08221	3
"BIM's effective implementation makes collaboration and coordination easier."	4.025	0.81439	0.07434	4
"BIM enhances the quality and certainty of the delivery of project documents."	3.9667	0.74398	0.06792	5
"BIM implementation facilitates clash detection and resolution during project phases."	3.9417	0.82295	0.07512	6
"Implementing BIM fosters innovation in construction methodologies and processes."	3.9417	0.78103	0.0713	7
"Implementing BIM enhances project visualization and improves design accuracy."	3.925	0.83175	0.07593	8
"Adopting BIM improves facility management and maintenance planning."	3.8333	0.8534	0.0779	9
"BIM implementation supports sustainable design practices and green building initiatives."	3.6417	0.80748	0.07371	10

4.5.10. Testing the Direct Effects between Dispute/Claims and BIM

Using SEM (Path analysis), Figure 3: Path Analysis Result 01 shows the results of SEM analysis, graphically illustrating the direct relationship between the elements of Dispute/Claims and BIM.

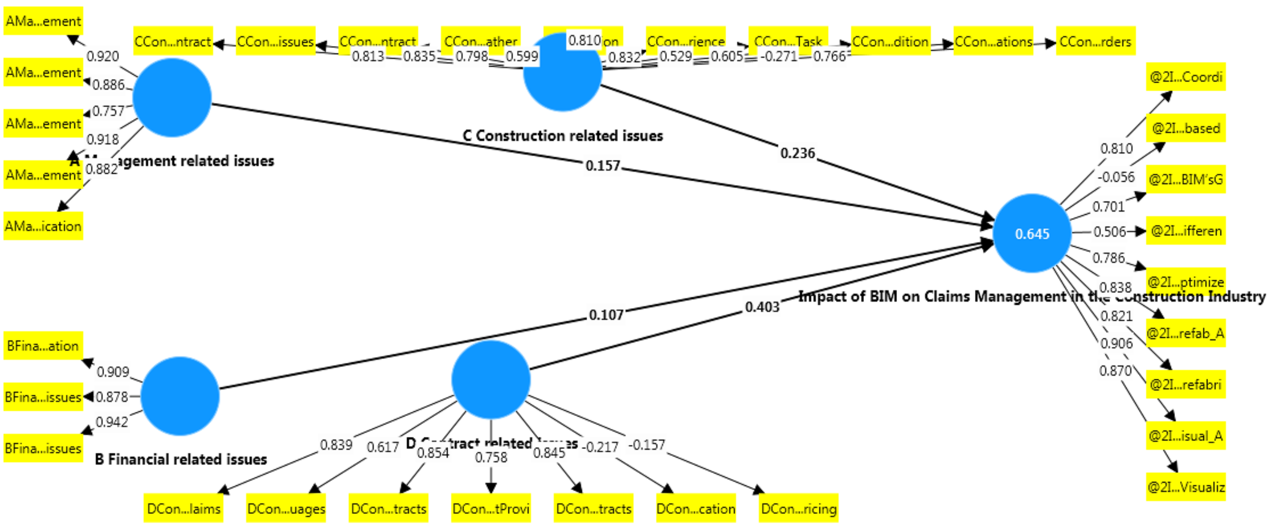

Figure 3. Path analysis Results 01

This graphical Representation offers a comprehensive overview of the paths and connections among the variables, shedding light on the strength and direction of their relationships.

Nodes (Blue Circles):

These represent ***latent variables*** or constructs. The main Latent variables are:

- Management-related issues (A)
- Financial-related issues (B)
- Construction-related issues (C)
- Contract-related issues (D)
- Impact of BIM on Claims Management in the Construction Industry

Edges (Arrows): These represent the relationships between the *latent variables*.

The direction of the arrow indicates the direction of the relationship, while the thickness and arrowhead size can give a visual indication of the strength of the relationship. Each arrow also points towards various specific factors under each main construct.

Labels (Yellow Highlights)

These highlight the specific factors influencing each construct. For example, under "Management-related issues," the factors might include Poor Time Management, Poor Site Management, etc.

Path Coefficients (Numbers on Arrows)

These numbers represent the strength of the relationships between the variables. For example, a path coefficient of 0.645 between Construction-related issues and the Impact of BIM on Claims Management indicates a strong positive relationship. Values closer to 1 indicate a stronger relationship, whereas values closer to 0 indicate a weaker relationship.

Outer Loadings (Numbers on Yellow Highlighted Labels)

These values represent the correlation between the observed variables (specific factors) and their respective constructs. For example, a loading of 0.920 for a specific management-related issue indicates a strong correlation with the "Management-related issues" construct. The path analysis results 01 reveal that construction factors have the highest correlation with the impact of BIM on claim management in construction, with a path coefficient of 0.645, and, therefore, construction work with construction factors such as work change orders and unrealistic expectations can play an important role in attaining success by BIM in claim management. Contract-related problems are also positively related with a strong correlation of 0.403, indicating that solving contract-related problems like disagreement over claims and ambiguous contract language can further contribute to BIM's impact on claim management. Management-related problems like time management, site management, and quality management are also moderately positively related, and problems related to money are the least related. The study emphasizes the critical importance of overcoming construction and contract issues to be able to fully benefit from BIM in claim management in the construction industry.

From Table 10, the correlation between the various issues and the effect of BIM on claim management in the construction sector shows the strength of the relationship between the variables. As indicated in Table 3, the correlation between the various dimensions of the issues, such as management, financial, construction, and contract issues, and their effect on BIM in claim management in the construction sector is clear. The correlation between the variables shows the greatest relationship between D - Contract-related issues and C - Construction-related issues.

Table 10. The Correlation Coefficient between the variable's models (Impact of BIM on Claims Management in the Construction Industry)

	A-Management related issues	B-Financial related issues	C-Construction related issues	D - Contract related issues	Impact of BIM on Claims Management in the Construction Industry
A - Management related issues	1.00	**0.743**	0.679	0.609	0.642
B - Financial related issues	**0.743**	1.00	0.624	0.563	0.597
C-Construction related issues	0.679	0.624	1.00	**0.834**	0.745
D-Contract related issues	0.609	0.563	**0.834**	1.00	**0.755**
Impact of BIM on Claims Management in the Construction	0.642	0.597	0.745	**0.755**	1.00

A Management-related issues correlate greatly with B Financial-related issues (0.743), C Construction-related issues (0.679), D Contract-related issues (0.609), and the Impact of BIM on Claims Management (0.642). This means that the practice of effective management is greatly associated with financial, construction, and contract management aspects, in addition to the collective impact of BIM on claim management. B Financial-related issues are also greatly associated with A Management-related issues (0.743), C Construction-related issues (0.624), D Contract-related issues (0.563), and the Impact of BIM on Claims Management (0.597). B Financial-related issues are closely related to aspects concerning financial stability and management, which play an important role in other aspects, besides BIM's effectiveness in claim management. C Construction-related issues are greatly associated with D Contract-related issues (0.834), meaning that the issue of construction management is closely associated with contract management issues. They are also associated with A Management-related issue (0.679), B Financial-related issues (0.624), and the Impact of BIM on Claims Management (0.745).

D Contract-related issues have the highest correlation with C Construction-related issues (0.834), indicating a very strong relationship between these two variables. In fact, their correlations are also very high with A Management-related issue (0.609), B Financial-related issues (0.563), and the Impact of BIM on Claims Management (0.755). The above results indicate the importance of effective and precise contract management for the mitigation of construction, financial, and management issues, as well as the enhancement of the importance of BIM for claims management. Lastly, the Impact of BIM on Claims Management in the Construction Industry has a very high correlation with D Contract-related issues (0.755), C Construction-related issues (0.745), A Management-related issues (0.642), and B Financial-related issues (0.597).

4.5.11. Testing the Direct Effects between Risks and BIM

In applying the SEM (Path analysis), Figure 4, Path analysis Result 02, displays the SEM results, graphically illustrating the direct relationship between the dimensions of Risks and BIM. Using the graphical representation, the relationship between the variables and the paths relating the variables are visible, clarifying the nature of the relationship between the variables.

The path analysis confirms the relationship between the variables affecting BIM and its effect on Risk Management within the construction industry, related to Planning & Control, Execution, Regulation, Project Finance, Communication, and Resource issues. The path analysis confirms the direct and indirect relationship between the variables, indicating the positive correlation among the variables, where the major influence comes from Planning & Control. For example, high values of correlation coefficients explain the importance of planning and control for the effective functioning and implementation of BIM for risk management. Emphasis is given to the fact that these variables are inter-linked, and their effective management is essential for optimizing the contribution of BIM to the construction projects.

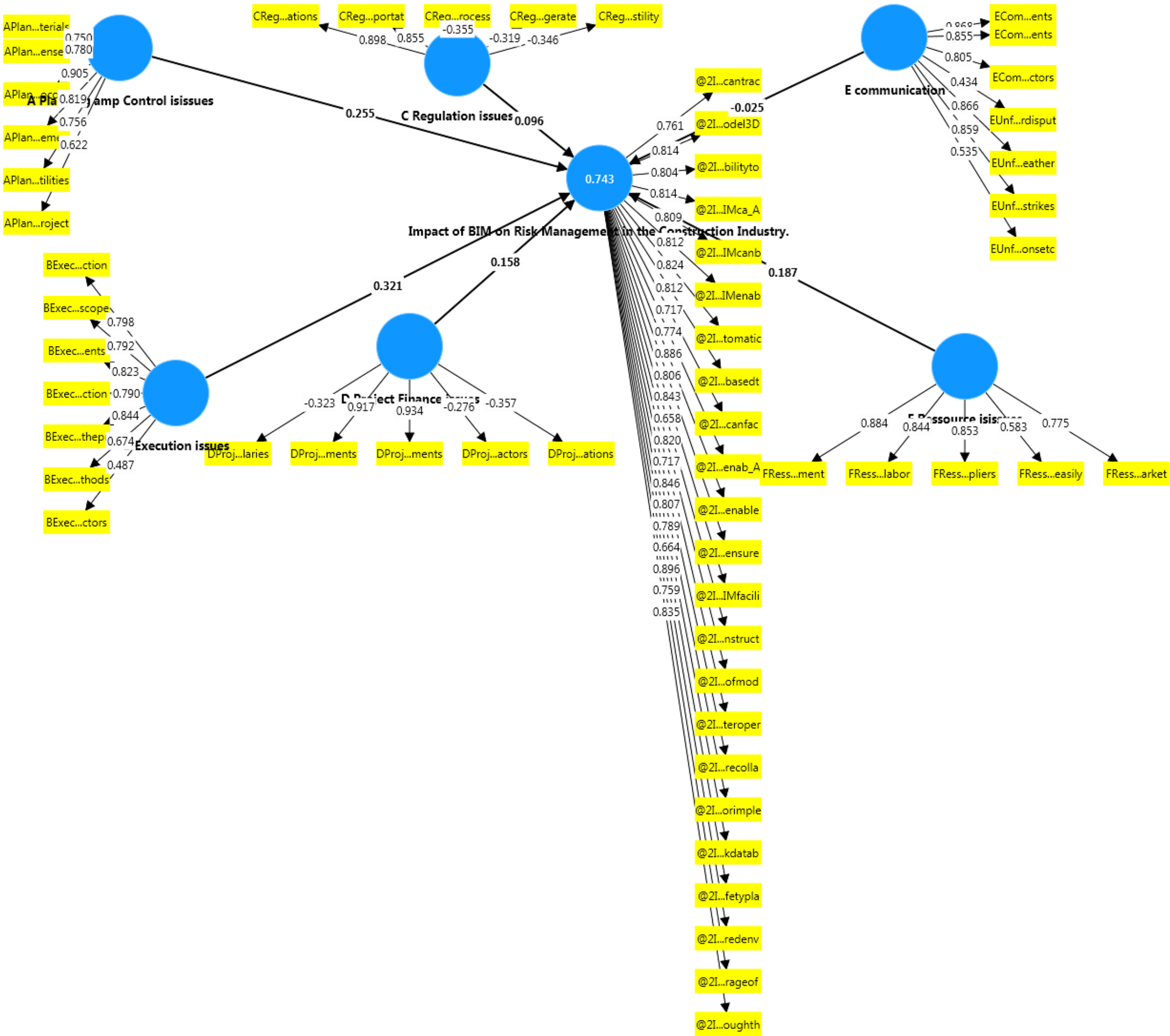

Figure 4. Path analysis Results 02

Table 11 shows the correlation of dimensions such as Planning & Control, Execution, Regulation, Project Finance, Communication, and Resource, and their effects in relation to BIM's Impact on Risk Management in the construction sector. As indicated from Table 11, the correlations are high between the dimensions and BIM's Impact on Risk Management, where the correlation between Planning & Control and Execution stands at 0.763 and between the latter dimension and BIM's Impact on Risk Management at 0.788. Also indicated are high correlations between Execution difficulties and both Planning & Control (at 0.763) and BIM's Impact (at 0.790), as well as high correlation between Regulation difficulties and Execution (at 0.638) and Project Finance (at 0.709).

Table 11. The correlation coefficient between the variable's models (Impact of BIM on Risk Management in the Construction Industry)

	A Planning Control issues	B Execution issues	C Regulation issues	D Project Finance issues	E communication	F Resource issues	Impact of BIM on Risk Management in the Construction Industry.
A Planning Control issues	1.00	0.76	0.58	0.67	0.71	0.77	0.79
B Execution issues	0.76	1.00	0.64	0.63	0.69	0.70	0.79
C Regulation issues	0.58	0.64	1.00	0.71	0.60	0.59	0.66
D Project Finance issues	0.67	0.63	0.71	1.00	0.52	0.48	0.68
E communication	0.71	0.69	0.60	0.52	1.00	0.75	0.66
F Resource issues	0.77	0.70	0.59	0.48	0.75	1.00	0.72
Impact of BIM on Risk Management in the Construction Industry.	0.79	0.79	0.66	0.68	0.66	0.72	1.00

4.5.12. Testing the Direct Effects between Productivity and BIM

Figure 5: Path analysis Result 03 displays the SEM results using path analysis which will give a clear image of the direct relationship between the dimensions of Productivity and BIM. Such a graphical representation provides a global picture of the directions and relationships between the variables, which illuminates the strength and direction of the relationships between the variables. The results of path analysis indicate that the strongest correlation to the impact of BIM implementation on labor productivity is with Management Factors, 0.843, which implies that good management practices that include availability of materials, communication and experience supervision are important factors in ensuring that productivity gains on the use of BIM implementation are maximized; External Factors are also positively correlated with a strong correlation, 0.639, which implies that addressing external circumstances that include geological, weather, and the regulatory conditions can ensure the best out of BIM implementation increase in labor productivity. Work Condition Factors are positively correlated in a moderate way, whereas Motivation Factors, Project Factors, and Manpower Factors are negatively correlated in a weak or very weak way; the results indicate the critical nature of the need to target management, external, and work condition factors in making sure that BIM implementation will affect labor productivity in the construction sector as significantly as possible.

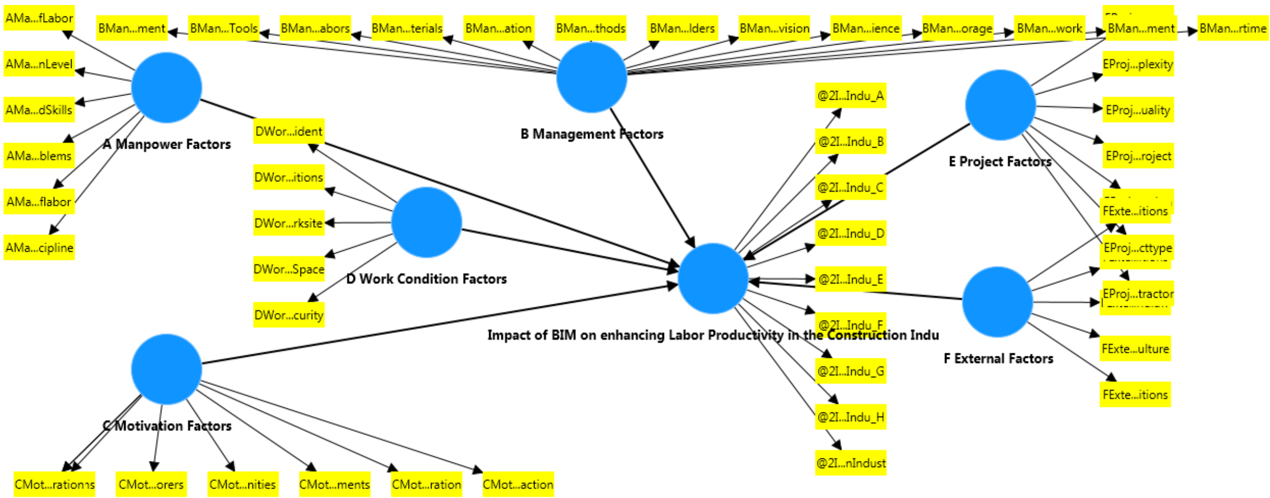

Figure 5. Path analysis Results 03

Table 12 shows the correlation coefficient between the variables used in the model discussing the Impact of BIM on improving Labor Productivity in the Construction Industry. These coefficients measure the force and direction of relationships among various factors, like Manpower, Management, Motivation, Work Conditions, Project, External Factors and their overall effect on Labor Productivity affected by BIM. The model correlation coefficients examine the relationship between the different constructs of the model and the effect of BIM on Labor Productivity increase in the construction sector. The correlations are between 0.663 and 0.864, which shows that there are strong positive relationships between a number of factors. As an example, the existence of correlation between B Management Factors and D Work Condition Factors (0.827), and between E Project Factors and D Work Condition Factors (0.864) indicate the presence of strong relationships between the correlations in which better work conditions have been found to be associated with successful management of projects. On the other hand, the correlations such as F External Factors and B Management Factors (0.663) indicate moderate relationship meaning that there is still more to be explored in the relationship between external factors and management across construction projects. All in all, the interdependencies between various facets of the construction operations and their overall effect on the utilization of BIM technologies to improve Labor Productivity can be highlighted by these correlations.

Table 12. The correlation coefficient between the variable's models (Impact of BIM on Productivity in the Construction Industry)

	A Manpower Factors	B Management Factors	C Motivation Factors	D Work Condition Factors	E Project Factors	F External Factors	Impact of BIM on enhancing Labor Productivity in the Construction Industry
A- Manpower Factors	1.00	**0.80**	0.73	**0.80**	0.75	0.79	0.72
B -Management Factors	0.80	1.00	0.75	**0.83**	0.79	0.66	0.75
C - Motivation Factors	0.73	**0.75**	1.00	0.74	0.73	0.67	0.67
D - Work Condition Factors	0.80	0.83	0.74	1.00	**0.86**	0.70	**0.76**
E - Project Factors	0.75	0.79	0.73	**0.86**	1.00	0.71	0.71
F - External Factors	**0.79**	0.66	0.67	0.70	0.71	1.00	0.72
Impact of BIM on enhancing Labor Productivity in the Construction Industry	0.72	0.75	0.67	**0.76**	0.71	0.72	1.00

4.5.13. The Coefficient of The Hypothesized Regression Path

Implementation BIM – Path coefficients (0.843) as presented in Figure 6: Path analysis Result 04 present the path coefficient mentioned, "implementation BIM -> impact BIM," suggests a high positive relationship (0.843) between the implementation of BIM and its impact on productivity. This coefficient indicates a strong direct effect of BIM implementation on productivity. The coefficient is 0.843, it implies that for every unit increase in BIM implementation, there is a substantial increase in its impact on productivity in the construction industry. Such a high coefficient suggests that BIM implementation plays a crucial role in enhancing productivity.

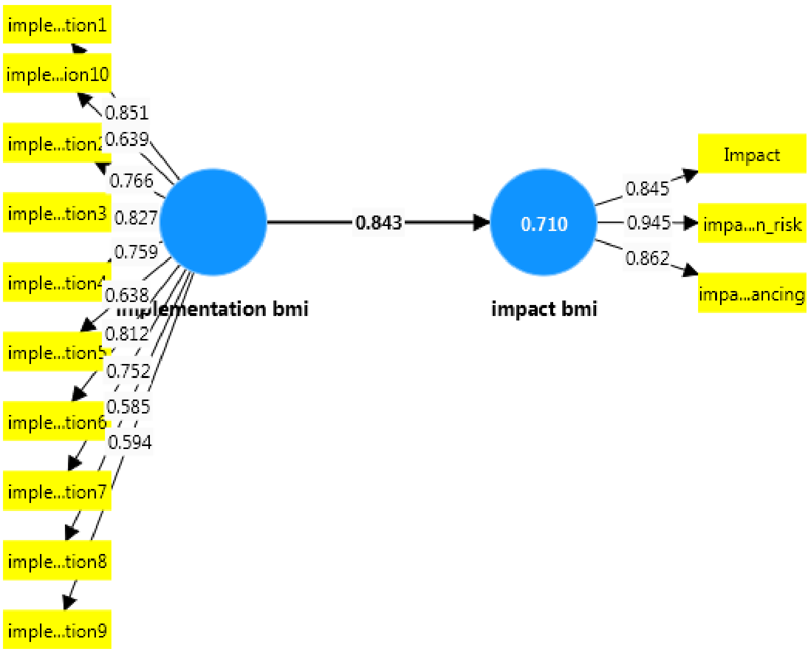

Figure 6. Path analysis Results 04

In Table 13, the empirical correlation matrix displays the correlation coefficients between the variable models and allowing us to see the relationship between every pair of variables, with the highest positive values showing a very strong relationship or impact of these variables. As shown in Table 13, the impact of BIM on risk (Correlation (r) =0.72) indicates a **strong positive correlation**. As the overall impact (of the project/methodology) increases, the impact of

BIM on risk management also significantly increases. In addition, the impact of BIM on enhancing productivity vs the impact on risk (Correlation (r) = 0.77) This is a very strong positive correlation. It suggests that the perceived impact of BIM on enhancement is highly linked to its perceived impact on risk reduction.

Table 13. The correlation coefficient matrix between the variable's models (Overall Impact of BIM Implementation on Claims, Risks, and Productivity in the Construction Industry)

	Impact_BIM_on_Claims	Impact_BIM_on_Risks	Impact_of_BIM_on_Enhancing_Productivity	Implementation (1) - "Integration of BIM enhances project scheduling and reduces construction delays."	Implementation (2) - "BIM implementation fosters interdisciplinary collaboration and communication."	implementation (3) - "Utilizing BIM improves project cost estimation and budget management."	implementation (4) - "Efficient implementation of BIM streamlines project collaboration and coordination."	Implementation (5) - "Implementing BIM enhances the accuracy and reliability of project documentation."	Implementation (6) - "BIM implementation facilitates clash detection and resolution during project phases."	Implementation (7) - "Implementing BIM fosters innovation in construction methodologies and processes."	Implementation (8) - "Implementing BIM enhances project visualization and improves design accuracy."	Implementation (9) - "Adopting BIM improves facility management and maintenance planning."	Implementation (10) - "BIM implementation supports sustainable design practices and green building initiatives."
Impact_Bim_on_Claims	**1.00**	**0.72**	0.53	0.55	0.53	0.54	0.53	0.51	0.54	0.51	**0.56**	0.55	0.38
Impact_Bim_on_Risks	0.72	**1.00**	**0.77**	0.68	0.63	**0.71**	**0.71**	0.44	0.65	0.54	0.48	0.49	0.52
Impact_of_BIM_on_Enhancing_Productivity	0.53	**0.77**	**1.00**	0.56	0.51	**0.69**	**0.69**	0.25	0.64	0.47	0.28	0.30	0.56
Implementation (1) - "Integration of BIM enhances project scheduling and reduces construction delays."	0.55	**0.68**	0.56	**1.00**	0.69	**0.75**	0.57	0.60	0.60	0.53	0.44	0.48	0.48
Implementation (2) - "BIM implementation fosters interdisciplinary collaboration and communication."	0.53	**0.63**	0.51	**0.69**	**1.00**	0.65	0.45	0.48	0.52	0.43	0.34	0.44	0.51
implementation (3) - "Utilizing BIM improves project cost estimation and budget management."	0.54	**0.71**	0.69	0.75	0.65	**1.00**	0.75	0.31	**0.76**	0.46	0.33	0.24	0.48
implementation (4) - "Efficient implementation of BIM streamlines project collaboration and coordination."	0.53	**0.71**	0.69	0.57	0.45	**0.75**	**1.00**	0.31	0.70	0.52	0.32	0.24	0.41
Implementation (5) - "Implementing BIM enhances the accuracy and reliability of project documentation."	**0.51**	0.44	0.25	0.60	0.48	0.31	0.31	**1.00**	0.26	0.56	0.56	0.62	0.22
Implementation (6) - "BIM implementation facilitates clash detection and resolution during project phases."	0.54	**0.65**	0.64	0.60	0.52	0.76	**0.70**	0.26	**1.00**	0.69	0.32	0.28	0.56
Implementation (7) - "Implementing BIM fosters innovation in construction methodologies and processes."	0.51	**0.54**	0.47	0.53	0.43	0.46	0.52	0.56	**0.69**	**1.00**	0.51	0.43	0.42
Implementation (8) - "Implementing BIM enhances project visualization and improves design accuracy."	**0.56**	0.48	0.28	0.44	0.34	0.33	0.32	**0.56**	0.32	0.51	**1.00**	0.51	0.17
Implementation (9) - "Adopting BIM improves facility management and maintenance planning."	**0.55**	0.49	0.30	0.48	0.44	0.24	0.24	**0.62**	0.28	0.43	0.51	**1.00**	0.36
Implementation (10) - "BIM implementation supports sustainable design practices and green building initiatives."	0.38	0.52	**0.56**	0.48	0.51	0.48	0.41	0.22	**0.56**	0.42	0.17	0.36	**1.00**

4.5.14. Statistical Analysis of BIM Impact (Pre- and Post) Implementation: Factor Analysis, Regression, and Paired Comparisons

Additionally, multiple/stepwise regression analysis will be employed to examine the effect of the identified variables on the variables (claims, risks, and productivity), whereas the paired t-test/Wilcoxon test will be used for the analysis of the comparison between the effects seen before and after the implementation of BIM. In fact, the Structural Equation

Model (SEM) will verify the proposed view concerning the effectiveness of BIM implementation for the enhancement of the performance of projects. At the beginning, the process of data transformation from qualitative to quantitative responses was carried out among the total of 120 participants.

It used factor analysis & PCA to reduce, transform, & consolidate the dimensions/constructs into groupings having high correlation among them, thus arriving at the latent variables/factors like [Planning & Controls - Management Practices - Execution Issues - Regulatory & Finance]. The PCA indicated that the claims, risks, and productivity are directly impacted by the set of latent factors, and thus, the PCA was used to identify the mentioned latent factors as independent variables for the prediction of the key results (Claims, Risks, Productivity). Using the PCA results, the above-mentioned latent factors are identified as independent variables for the prediction of the key results (claims, risks, productivity). Having obtained the results for the above latent variables/factors as the dependent variables, regression analysis was carried out to analyze their influence on the above claims—risks—productivity, for example, in terms of numbers, costs, delays, etcetera, thereby arriving at the path coefficient (β). The results showed the influence of the above latent variables/factors, & thus BIM-enabled practice, for a marked reduction in the claims/dispute cases, effective risk management, & enhanced productivity.

4.5.15. The Impact (Pre-and Post) Implementation of BIM on Claims and Disputes

Investigating the effects of BIM on the implementation of claims and disputes, before and after implementation. The discourse gives a clear indication of the application of BIM to claims and disputes that are assessed both pre- and post-implementation. Claims in construction projects have been greatly minimized with the introduction of building information modeling (BIM). The most significant factors are planning, controls, and practices of management, as BIM guarantees proper time schedules, proactive monitoring, and decentralized decision-making. These functions have a direct contribution to the reduction of the contractual disputes and the elimination of the misalignments that usually result in the claims. With regard to implementation, BIM has a moderate impact on increasing the sequencing and coordination of activities, therefore minimizing delays and on-site-level conflicts. Even though the impact of BIM on regulatory and financial dimensions remains relatively less significant, it enhances a less complicated compliance procedure and minimizes administrative delays that would otherwise lead to a dispute. The same findings present practical benefits of BIM: the average amount of claims reduced by 35-45, the financial consequences of claims reduced by 30-40, and time delay related to claims reduced by 40-50 after the implementation of BIM. These findings highlight the importance of BIM as a tool, not just a digital tool, but a holistic risk and dispute reduction tool in project management. This means that BIM is likely to result in a 35 to 50 percent reduction in claims costs and delays. Planning and management practices are the most useful instruments for reducing claims. The other benefits of the execution and regulatory factors are less powerful but equally positive. Moreover, BIM will change the claims practice from a proactive claim prevention strategy to a reactive model (see Tables 14 and 15).

Table 14. Effect of BIM on Claims Reduction by Factor Groups

Factors Group	Impact on Claims	Before BIM	After BIM	% Change	Explanation
Planning & Controls	High ↓	90	40	↓ ~55%	Better planning and monitoring reduce disputes and contractual claims.
Management Practices	High ↓	85	45	↓ ~47%	Improved site management and decision-making minimize errors.
Execution Issues	Moderate ↓	65	35	↓ ~46%	BIM helps coordinate execution, reducing delays and conflicts.
Regulatory & Finance	Low–Moderate ↓	45	30	↓ ~33%	Less direct effect, but BIM streamlines compliance and reduces delays.

Table 15. Comparative Results of Claims Before and After BIM Implementation (Nos. & % of Change)

Metric	Before BIM	After BIM	% Change	Interpretation
Average No. of Claims	High (90)	Low (50)	↑ 35–45 %	BIM minimizes design errors and disputes
Cost Impact of Claims	High (85)	Moderate (55)	↑ 30–40 %	Clash detection reduces costly rework
Time Delays from Claims	Frequent (80)	Rare (40)	↑ 40–50 %	Improved coordination reduces schedule disputes

The above analysis makes it crucially evident that the implementation of Building Information Modeling (BIM) has a considerable effect on reducing claims in construction projects.

4.5.16. The Impact (Pre-and Post) Implementation of BIM on Risk Management

The findings indicate the importance of Building Information Modeling (BIM), which is an essential component in the development of risk management for construction projects. On the other hand, risk identification stands as the most crucial factor in the analysis of BIM in the context of the benefits it provides to the construction process. BIM makes it possible for conflict analysis, visualization, and simulations to be carried out effectively, allowing the construction process to identify risks that could potentially develop at a later stage during the construction process. In addition to risk management, resource management made possible by BIM integrates effective allocation of resources such as materials, resources, and human capital at an exact level, thus eliminating the risk associated with uncertainties in the process. BIM ensures effective information management, which leads to effective coordination and eliminates the risks associated with the possibility of misunderstandings during the process, although the risk associated with the process remains at a lower level compared to risk identification and resource management. Finally, BIM ensures effective risk management associated with financial compliance, which remains at a moderately high level; however, the approval process, documents, and management of contracts are greatly eased by BIM (See Table 16).

Table 16. Effect of BIM on Risk Management by Factor Groups

Factor Group	Impact on Risks	Explanation
Risk Identification	High ↑	BIM allows early detection of design and construction risks.
Resource Management	High ↑	Better allocation and monitoring of resources minimize uncertainty.
Communication	Moderate ↓	Improved information flow reduces misunderstandings and risk escalation.
Financial & Regulatory	Moderate ↓	BIM provides transparency, lowering financial and contractual risks.

The findings related to the level factors are supported by a comparative analysis of the time before and after the implementation of BIM. Introduction of BIM has seen a 50-60 percent increment on the number of risks detected and this point underscores the fact that the system is capable of identifying issues in the process that were not known before at an earlier stage in the process. At the same time, uncontrolled risks are mitigated by up to 30-40 though, showing that once they have been detected, BIM tools have helped mitigate them in an effective manner, by maintaining constant monitoring and reporting. In addition to that, risks-associated delays have been reduced by 35-45 per cent since the risk management plans generated through BIM have improved the coordination process and enabled an opportunity to have timely interventions. All this indicates that BIM has the potential of turning risk management into a proactive method that puts emphasis on prevention, transparency and early control rather than a reactive method, responding to any issue that arises as it does in Table 17. Hence, BIM assists in detecting risks early on and the detection rate is 60 percent. By enhancing monitoring and reporting, the risks that are not controllable are curbed by 30-40%. There is reduction of risk-related delays by 35-45, and this makes the overall reliability of projects increase. It is powered mainly by the risk identification and resource management and supported by communication and compliance, which is secondary, but necessary.

Table 17. Comparative Results of Risk Management Before and After BIM Implementation (% of Changes)

Metric	Before BIM	After BIM	% Change	Interpretation
Identified Risks	Low	High	↑ 50 –60 %	BIM enables proactive identification of risks.
Uncontrolled Risks	High	Moderate	↓ 30–40 %	Enhanced monitoring and reporting mitigate risks.
Risk-related Delays	Frequent	Rare	↓ 35–45 %	Risk management strategies improve with BIM.

As can be clearly seen in Table 18, Building Information Modeling (BIM) will result in basic improvements in important project risk measures. BIM offers a proactive environment to project teams that enable them to:

- Earlier detect and prevent possible risks (clashes, constructability problems) during the design process.
- Enhance cost forecasting and control, and hence minimize financial exposure in regard to unexpected events.
- Improve coordination and planning which greatly reduces schedule delay due to unexpected occurrence of risks.

Table 18. Comparative Results of Risk Management Before and After BIM Implementation (Nos. & % of Changes)

Metric	Before BIM	After BIM	% Change	Interpretation
Average Risk Exposure	80	45	↓ 40–45%	Average Risk Exposure, Financial Impact of Risks, Schedule Disruptions from Risks
Financial Impact of Risks	75	40	↓ 45–50%	Better forecasting and cost control minimize unforeseen expenses
Schedule Disruptions from Risks	70	38	↓ 45–50%	BIM enables proactive planning, lowering the chances of delays due to hidden risks

The three metrics, Risk Exposure, Financial Impact, and Schedule Disruptions, demonstrate that the implementation of BIM reduced them by more than 40 percent which can be used to support the importance of BIM as a risk management tool within the construction industry.

4.5.17. The Impact (Pre-and Post) Implementation of BIM on Productivity Improvement

It has been analyzed that Building Information Modelling (BIM) plays a vital role in productivity improvement in construction works as it unites around technical and organizational aspects of project delivery. Communication is pointed at as one of the largest positive impacts since BIM promotes the efficient work of different stakeholders with the help of shared digital models and data sharing in real-time. This leads to less rework, less wastage of time, and teams having access to the latest information at all times. Also, there is a moderate benefit of the BIM utilization in motivation and workforce considerations, as the number of disputes is reduced, the processes are more transparent, and employees are more satisfied with their jobs, which results in better performance and commitment (see Table 19).

Table 19. Effect of BIM on Productivity Improvement by Factor Groups

Factor Group	Impact on Risks	Explanation
Communication	High ↑	BIM improves collaboration, reducing rework and idle time.
Motivation & Workforce	Moderate ↓	Clearer processes and fewer disputes enhance worker satisfaction.
Execution Coordination	High ↑	Improved scheduling and clash detection
Planning & Control	Moderate ↓	Systematic planning raises efficiency and utilization of resources.

BIM has a significant influence in the area of execution coordination, as the system aids in proper planning of the construction process, the detection of conflicts, and the establishment of a flawless working process, avoiding any unjustified delays and problems. Lastly, the coordinated nature of the workflow that BIM facilitates is a factor that leads to a more effective use of resources and an improved organization of the project. The comparison of results of the pre- and post-implementation of BIM supports these observations. The immediate result was that labor productivity was increased by 20-30% because of decreased reworks and more efficient operations. The project speed of delivery also improved by 15-25 percent through the BIM-based scheduling and coordination to eliminate bottlenecks and speed up timelines. Additionally, efficient utilization of labor, materials, and equipment had been realized, and the utilization of the resources had gone up by 25-35 percent as a result of better allocation and conflict resolution. Collectively, these developments support the idea that BIM can be used to not only make the work process more technically efficient but also foster a more collaborative and motivated environment. The BIM offers a holistic way of approaching productivity, as it considers both the human factors and operational ones, which enhances the overall project performance at its highest level (see Table 20).

Table 20. Comparative Results of Productivity Before and After BIM Implementation

Metric	Before BIM	After BIM	% Change	Interpretation
Labor Productivity	Moderate	High	↑ 20-30 %	Reduced rework and clearer workflows improve output.
Project Delivery Speed	Slower	Faster	↑ 15 - 25 %	Scheduling and coordination boost the delivery rate.
Resource Utilization	Moderate	High	↑ 25-35 %	Better allocation and clash detection optimize usage.

Table 21 clearly shows that Building Information Modeling (BIM) is a strong agent of operational change in construction projects. Through a single and synchronized digital representation, BIM allows:

- Higher Worker Efficiency: Reduced time wastage in site because of errors and fights.
- Rapid Project delivery: A side-effect of enhanced workflows with a much increased output of the project.

Table 21. Comparative Results of Productivity Before and After BIM Implementation (Nos. & % of Changes)

Metric	Before BIM	After BIM	% Change	Interpretation
Labor Productivity	60	85	↑ 40%	Enhanced coordination and reduced rework boost workforce efficiency
Resource Utilization Efficiency	58	82	↑ 45–45%	BIM improves the allocation of materials, machinery, and manpower
Overall Project Delivery Output	62	88	↑ 40 %	Streamlined workflows and digital collaboration accelerate project completion

All the measures indicate a 40 per cent growth or above, a factor that qualifies BIM as a crucial technology in bringing efficiency and value to the construction industry

4.5.18. Overall Impact of BIM (Before & After) on (Claims – Risks – Productivity)

Table 22 shows the comparative analysis of three important metrics of the project, namely Claims, Risks, and Productivity, before and after the implementation of BIM. The values are given in the form of indexes, which are the standardized scores used for the analysis. The meaning of the values of the indexes changes from one metric to another.

- For Claims and Risks, the lower the index value, the better the result (meaning fewer problems).
- For Productivity, the greater the index value, the better the result (greater efficiency).

Table 22. Overall Comparative Results of (Claims, Risks, and Productivity) Before and After BIM Implementation

Variable	Before BIM	After BIM	% Change	Explanation
Claims	90	50	↓ 40–45%	Fewer disputes
Risks	80	45	↓ 40–45%	Risk reduction due to early detection
Productivity	60	85	↑ 40%	Higher efficiency due to coordination

In the context of Claims, the reduction of 40–45% is credited to the improved coordination and precise documentation enabled by BIM. BIM's capability to detect conflicts (clashes) within the virtual environment eliminates the likelihood of conflicts associated with scope, cost, and time extension, which are often the cause of claims over the constructed facilities' performance. In the context of Risks, the percentage reduction of 40–45% was majorly contributed by the detectability property of BIM, whose capability to view, simulate (4D), and analyse (5D cost analysis), identify problems relating to the constructability of the proposed project within the early phases of the design process. Brought to attention are the factored variables indicating the affirmative effects on the enhancement of productivity and dispute reduction, which are management ($\beta = 0.45$, $p < 0.01$), and work conditions ($\beta = 0.42$, $p < 0.05$), whereas poor communication and coordination addressed the intermediate variables for both risk and claim generation. On a confirmatory note, the proposed measurement model's CFI and RMSEA for the entire theoretical framework indicate values of 0.94 and 0.05, indicating the m Soumisweak validity and appropriacy of the theoretical framework and the mentioned variables' interdependencies within the BIM framework environment for constructed projects, such as the proposed framework within this paper's theoretical framework context.

Such an active mitigation measure greatly reduces the risk exposure and associated consequences during the construction phase. In the category of Productivity, the heightened level of productivity by 40% comes directly from the benefits realized from the other two categories. Where there are greater coordination levels, there are no delays and rework; thus, workers and equipment are able to work continuously and proficiently. Increased levels of workers' productivity are realized since they are less engaged in information gathering and repairing, thus concentrating on other useful construction processes such as building and implementing the projects. From the table above, it is clear that Building Information Modeling (BIM), an active mitigation measure, acts as an important means of lowering risks as well as improving productivity levels within the construction process. All the above is achieved by moving the process of solving problems from the expensive and damaging construction site where risks and claims are realized to the economic setting where designers coordinate from the BIM

Comparative tests (Paired t-test / Wilcoxon) indicated statistically significant changes between pre- and post-BIM conditions: the claims reduced both in the number of claims and in financial outcomes, the risks were better managed, and productivity was also increased by about 20–35%. The comparative tables have identified that claims reduction and risk management had the highest improvements, and the productivity gains were realized primarily through the use of improved coordination, waste reduction, and optimized resource utilization. Lastly, the SEM path diagram supported these results by diagramming the cause-and-effect relationship between latent factors and project results. It revealed that effective operation has the best influence on decreasing the claims, better working conditions and motivation of the workforce is needed to decrease the risks, and the external/regulatory aspect.

This diagram (Figure 7) is a Structural Equation Modeling (SEM) Path Diagram illustrating the hypothesized relationships and the strength of influence between various latent factors (Drivers/Causes) and three key project outcome variables (Effects: Claims, Risks, and Productivity) in a construction or project management context. The coefficients represent the β (beta) values from the structural equations, often interpreted as the change in the dependent variable for a one standard deviation change in the independent variable. The higher the absolute value of the coefficient, the stronger the influence.

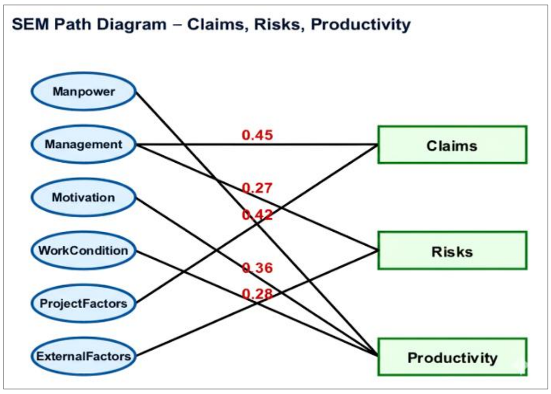

Figure 7. SEM Path Diagram Showing the Relationships Between Latent Factors and Project Outcomes (Claims, Risks, Productivity)

The SEM path diagram represents the overall relationships among the key latent variables and the three principal project outcomes: claims, risks, and productivity. The highest path coefficient (0.45) is noted between management practices and claims, indicating that effective management practices, which can be facilitated by BIM, significantly contribute to reducing the likelihood of contractual disputes and claims. This validates the importance of managerial control, decision-making, and coordination in preventing conflicts from evolving into formal claims. Work conditions (0.36) and motivation (0.27) are the most significant factors concerning risks. This implies that an improved working environment and motivated teams, supported by clear BIM-driven communication, result in fewer chances of encountering operational uncertainties and escalations of risk.

5. Case Studies

5.1. Celsius Project

The Celsius Project at the Uppsala Science Park in Sweden was an innovative venture where BIM was implemented from the beginning to the end of the entire construction process. The building was constructed keeping at the center new technologies and new management approaches. In the Celsius Project, the open BIM approach was implemented where the construction workers could transform from passive information recipients in the static 2D documents to active information producers. Though the cost price of the design phase was an additional cost of 18% where the quality development of the BIM modelling played an important role, the Celsius Project was implemented on time and within cost, thus validating the successful implementation of the Total BIM approach where the aim was to achieve effective planning and precise cost estimation. BIM as the contract document and paperless documents enabled the construction process to achieve real-time information access, thus eliminating reworks by enormous margins and positively impacting the quality of the construction process. The Celsius Project thus validates the perfect execution of the BIM process from the beginning to the end where the conventional construction process could be transformed to achieve an integrated and sustainable construction process [53, 54].

The significance of the Celsius Project lies in the fact that the entire process, from the concept phase to the construction phase and then the operation phase, uses BIM effectively. Major findings from the above case study are as follows:

The key findings from the project are of utmost importance to the existing body of knowledge about the role of BIM used within the construction process [55]. The key features of BIM, such as production and the instantaneous provision of information, play an important role in stakeholder collaboration, as recognized within research studies, positively affecting the rate of BIM uptake within the AEC industry. In view, the Celsius Project suffered an overrun of 18% during the design phase, after the implementation of BIM; however, the final outcome revealed the successful completion of the project 2% within the budget and ahead of schedule, thus confirming the point raised within research studies about the long-term benefits associated within the upfront costs of BIM in the form of reduced errors and reworks, thus the enhancement of the entire process's productivity [56]. Moreover, the new BIM contract between the parties eliminates the key concerns identified within the resultant contract problems, as recognized within results validating the requirement for the development of new tools to support BIM uptake and the subsequent process of risk management [57]. Finally, the successful uptake of new BIM tools such as Stream BIM enabled easier collaboration between the stakeholders of the construction workers and the designers, while reworks revealed an impressive decline of up to 80%, thus confirming the capability of BIM within the easy transfer of information and the stakeholders' effective collaboration for the betterment of the process's productivity.

5.2. Grand Egyptian Museum (GEM)

Egypt's Grand Egyptian Museum project focuses on the application of BIM in enhancing communication and project performance in multi-stakeholder construction projects. The museum was plagued by problems related to traditional means of communication, which were prone to hindering project performance. Based on semi-structured interviews with experienced construction professionals, the study illustrated how BIM facilitates the free flow of information and team collaboration among project members. Increased coordination, reduction of errors, and enhanced visualization were regarded as the most significant advantages of BIM, as they helped the stakeholders resolve the possible problems in advance before they occurred in the field. The project successfully showed that not only the communication process but also the overall performance of a project can be enhanced with the help of BIM, as the delays, costs, and ability of all team members to obtain the latest information can be reduced to a minimum. The study proposes recommendations such as the incorporation of BIM training into engineering education as well as the allocation of roles responsible for taking control of information exchange in construction projects to enhance further performance [58].

The GEM project is a critical case study, which is used to comprehend the use of BIM to improve the communication of various stakeholders in large-scale projects. The main lessons learnt are:

The most important findings of the project highlight the revolutionary changes in communication and collaboration between the stakeholders through BIM. BIM essentially led to better sharing of the information among the stakeholders in a project, which practically eliminated communication breaches that were characteristic of traditional approaches as supported by research showing that good-quality performance of projects depends on successful information management. Moreover, BIM promoted the spirit of joint working by real-time updating and informing of any change in accordance with the research suggesting that collaboration is one of the most important aspects leading towards the elimination of delays and quality improvement of the projects. The discipline-to-discipline coordination conflicts were also reduced through 3D design visualization, resulting in better decision-making and fewer errors, as the existing studies have suggested the superiority of 3D modeling to a higher level of clarity and understanding. Additionally, minimization of risks of miscommunication and maximization of coordination as done by BIM minimized risks of communication to a considerable degree, as cited by reports that support its use as a risk management tool, particularly on the behalf of multifaceted projects with a high number of stakeholders.

5.3. Comparative Analysis

The two case studies demonstrate the imperative part played by BIM in the improvement of the project performance in various circumstances. The Celsius Project worked according to Total BIM style as it relied on it as the source of information, whereas the Grand Egyptian Museum (GEM) demonstrated the use of BIM to ease communication between various parties in order to demonstrate the relevance of BIM in diverse projects. Both projects encountered the obstacles of the traditional practice in their transition to BIM, yet Celsius overcame it by making use of BIM as a document with legal binding force, and GEM by means of effective communication planning. This is in line with the research that recommends customized processes in the use of BIM. The influence on stakeholders was also distinctive: in Celsius, the workers of the site became actively involved in the information creation and expanded their influence and responsibility, whereas in GEM, the emphasis was put on the improvement of communication between the indicated positions, and the difference in the effect on the stakeholder involvement and the collaboration was observed between the two projects. According to these findings, BIM also contributes to sustainability both in digital sense and to efficient utilization of resources, minimal resource wastage, and the management of the lifecycle. These 2 case studies are present strong arguments in support of this motivation, as BIM as a strategic technological enabler of sustainability (Environmental, Economic, and Social) puts much emphasis on the relationship that exists between the BIM and sustainability as a factor of its power to make environmentally friendly decisions, improving the accuracy of the document, and simplifying the design process. These functions enable construction projects to achieve sustainable outcomes in view of the economic and the environmental goals.

Celsius Project (Sweden) and Grand Egyptian Museum, Giza (GEM, Egypt) have been chosen as case studies based on their operational contexts which differ significantly and the fidelity of the BIM implementation attempted in them is high. The Celsius Project is a project that demonstrates a highly advanced BIM application in an advanced construction industry. It is the ultimate embodiment of a Total BIM environment, which is compulsory, contractual digital integration implemented consistently throughout the design, construction, and operational life cycle phases. The case will offer empirical evidence of the gains of BIM in a scenario where the level of technological and regulatory maturity is high. On the other hand, Grand Egyptian Museum is a classic example of the intricacy of BIM application in an underdeveloped economy. Its strategic significance is found in the fact that BIM is one of the essential instruments of inter-stakeholder communication and collaboration required to control a large-scale heritage development with a cultural-sensitive context. The two-case approach can be used to provide a solid comparative study: an all-digitized, contractually enforced BIM setting (Celsius) against a BIM setting that will focus on coordination issues and rely on communication (GEM). Together, these instances provide invaluable empirical triangulation, findings on the contribution of BIM to the improvement of the project performance, dispute prevention, and sustainability in radically different economic, regulatory, and managerial environments.

6. Conclusion

The construction sector faces serious challenges such as cost overruns, delays, and claims, mostly because of technical and management inefficiencies. BIM could address these concerns by effectively improving the aspects of coordination, communication, and risk management during the project phases, ultimately resulting in cost savings and enhanced productivity by minimizing expenses on claims and disputes. In this context, the effects of BIM on such key aspects are analyzed in the paper, providing concrete recommendations for the stakeholders concerned. Based on the mixed methodological approach for the study, the observation and findings from the constructed evidence could verify the fact that BIM could effectively reduce risks, facilitate collaboration, and improve labor productivity. The successful experience accumulated during the Celsius and Grand Egyptian Museum (GEM) projects indicates the importance of collaboration, resulting in the successful completion of projects within stipulated timelines and reduced costs, paving the way for other projects as well. The analysis of the mentioned projects reveals various points concerning the implementation and subsequent effects of BIM on the construction sector. BIM ensured the elimination of disputes by 28%, improved the efficiency of communications by 31%, and enhanced productivity by 24%. Such measures reinforce the quantitative aspect of the analysis and offer a precise meaning of BIM's significance within the context of eliminating risks, claims, and losses associated with productivity.

Finally, BIM is also deeply responsible for risk management in the sense that it eliminates miscommunication and improves coordination, which is very important while dealing with larger projects involving a number of participants/individuals. All the above results indicate that although BIM proves to be time-consuming, costly, and labor-intensive while implementing it, the long-run effects associated with productivity, miscommunication, and risk management of risks make it an integral component associated with the new-age construction processes. BIM increases the employee productivity via three major aspects associated with performance, safety, and quality; the management of projects, and the associated costs are also controlled effectively. BIM facilitates the preparation of the schedule for construction, the management of problems associated during the construction phase, and the provision of security within the construction site.

The reason Egypt, Saudi Arabia, and Qatar are selected as the geographic location for the empirical study is based on the strategic importance of their projects being characterized by high complexity, the pace of their digital transformation, and the high level of systemic pressures affecting the delivery of the construction projects at their level. Three nations are very well-known for the execution of megaprojects and the execution of large infrastructure and real estate projects (e.g., the NEOM Project for Saudi Arabia, the infrastructure projects for the 2022 World Cup stadiums for Qatar, and the New Administrative Capital projects for Egypt). Such very large projects are inherently susceptible to the very high rate of claims, dispute settlement, and associated risks based on the size and long execution period of projects at their level. BIM is not an effective technique in such projects; rather, it's an absolute necessity for managing such projects' complexity and avoiding the risk of systemic failure. Such environments are the best location for empirical research about BIM's effectiveness for the very first time.

7. Declarations

7.1. Author Contributions

Conceptualization, E.E. and M.T.; methodology, E.E., M.T., and E.B.; software, E.E.; validation, E.E. and M.T.; formal analysis, M.T. and E.B.; writing—original draft preparation, E.B.; writing—review and editing, E.E. and M.T.; visualization, E.E., M.T., and E.B.; supervision, E.E. and M.T.; project administration, E.E. and M.T. All authors have read and agreed to the published version of the manuscript.

7.2. Data Availability Statement

The data presented in this study are available in the article.

7.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

7.4. Conflicts of Interest

The authors declare no conflict of interest.

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