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Optimizing construction processes and improving building performance through data engineering and computation

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Abstract

The use of manual labour and physically demanding building techniques is a hallmark of the construction industry. However, recent technological developments have given rise to a rising tendency in the construction industry towards digitalization and data-driven decision-making. The purpose of this study is to investigate how data engineering and computing are used in the construction sector and how they affect building methods. The study depends on a thorough analysis of the literature, which includes 26 pertinent papers from scholarly publications and business reports. The results imply that computing and data engineering can dramatically enhance building procedures and results. Particularly, these technologies make project planning, resource allocation, and risk management more precise and effective. The use of data can also result in more accountability and transparency in building projects, which can save costs and enhance overall project performance.

The study also looks at the challenges involved in applying data engineering and computation in the construction sector, including problems with data security, privacy, and quality. The study also emphasises the requirement for more thorough data management plans as well as the creation of industry-wide standards and best practices. The results have important ramifications for experts in the field, academics, and decision-makers, and they can guide future initiatives to incorporate data-driven methods into the construction sector.

Keywords: Data engineering; Computation; Construction industry; Building performance; Construction processes; Artificial intelligence

1. Introduction

The construction industry is a vital sector that drives economic growth and development worldwide. It is a complex and multifaceted industry that involves various stakeholders, such as designers, engineers, contractors, and suppliers, among others [1]. The production of a significant amount of data throughout a project's lifespan is another characteristic of construction company operations. These data consist of details about project management, building information modeling (BIM), and sensor data from machinery used for construction. [2].

Data engineering and computation are emerging as critical disciplines in the construction industry. Data engineering involves managing and processing large amounts of data to ensure its quality and accessibility, while computation involves using computational tools and techniques such as artificial intelligence (AI), machine learning, and data

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analytics to analyze and derive insights from this data [3]. The integration of data engineering and computation in construction is transforming the way buildings are designed, constructed, and maintained [4].

The purpose of this research paper is to explore the importance of data engineering and computation in the construction industry. Specifically, this paper aims to discuss how data engineering and computation can be integrated into the construction process to optimize construction processes and improve building performance. The paper will also examine the challenges and opportunities associated with using data engineering and computation in construction.

Finally, the paper will provide case studies that demonstrate the use of data engineering and computation in construction. These case studies will show how data engineering and computation have been used to optimize construction processes and improve building performance. The paper will analyze the results of these projects and discuss the lessons learned.

1.1. Research Rationale

The construction industry has historically been slow to adopt new technologies and innovative approaches. However, with the growing demand for sustainable, energy-efficient, and cost-effective buildings, the industry is increasingly turning to data engineering and computation to optimize construction processes and improve building performance [5]. This research aims to explore the importance of data engineering and computation in the construction industry and to identify the challenges and opportunities associated with using these disciplines in construction.

The need for this research arises from the increasing importance of data engineering and computation in the construction industry. As the demand for sustainable, energy-efficient, and cost-effective buildings continues to grow, the industry is increasingly turning to these disciplines to optimize construction processes and improve building performance. However, the integration of data engineering and computation in construction is still in its early stages, and there is a need to explore the challenges and opportunities associated with using these disciplines in construction.

This study seeks to fill this gap by throwing light on how computing and data engineering is used in the building sector and highlighting the possible advantages, difficulties, and possibilities that come with their application. The results of this study may be used to design methods for overcoming these challenges and taking advantage of these chances to enhance building performance.

1.2. Research Objectives

The objectives of this research are:

- To explore the use of computation in construction and how it is changing the way buildings are designed, constructed, and maintained.
- To discuss the integration of data engineering and computation in construction and how it can optimize construction processes and improve building performance.
- To identify the challenges and opportunities associated with using data engineering and computation in construction.
- To provide case studies that demonstrate the use of data engineering and computation in construction and analyze the results of these projects.

1.3. Research Questions

The research that will guide this research are:

- How is computation changing the way buildings are designed, constructed, and maintained?
- How can data engineering and computation be integrated into the construction process to optimize construction processes and improve building performance?
- What are the challenges and opportunities associated with using data engineering and computation in construction?
- What are the lessons learned from case studies that demonstrate the use of data engineering and computation in construction?

1.4. Significance of the Study

The findings of this research will be significant for multiple stakeholders in the construction industry, including designers, engineers, contractors, and suppliers, among others. The research will provide insights into the importance of data engineering and computation in construction and the potential benefits of using these disciplines to optimize construction processes and improve building performance. The research will also identify the challenges and opportunities associated with using data engineering and computation in construction, which can inform the development of strategies to overcome these challenges and leverage these opportunities.

1.5. Delimitations

This research will focus on data engineering and computation in the construction industry. The research will not cover other areas of the construction industry, such as project management or procurement. The research will also not cover specific data engineering or computational techniques or tools in detail but will provide a broad overview of these disciplines.

In addition to the delimitations mentioned earlier, this research will also be limited in terms of geographic scope. The research will focus primarily on the use of data engineering and computation in the construction industry in developed countries. The research will not cover the use of these disciplines in developing countries, where construction practices and technologies may differ significantly from those in developed countries. Another delimitation of this research is that it will primarily focus on the use of data engineering and computation in the construction of buildings rather than infrastructure projects, such as roads and bridges. While some of the principles and techniques of data engineering and computation may apply to infrastructure projects, these projects may have unique characteristics and requirements that are beyond the scope of this research.

Finally, this research will be limited to the published literature and case studies related to data engineering and computation in construction. While primary research, such as surveys and interviews with industry professionals, may provide additional insights into the use of these disciplines in construction, such research is beyond the scope of this study.

1.6. Literature review

1.6.1. Introduction

The literature on data engineering and computing in the construction sector is thoroughly reviewed in this chapter. The literature review will examine the evolution of these disciplines in construction and their applications in various aspects of the construction process. The chapter will also explore the challenges and opportunities associated with using data engineering and computation in construction and the potential benefits of integrating these disciplines into the industry.

1.6.2. Evolution of Data Engineering and Computation in Construction

The construction industry has traditionally been slow to adopt new technologies and innovative approaches [6]. However, with the growing demand for sustainable, energy-efficient, and cost-effective buildings, the industry is increasingly turning to data engineering and computation to optimize construction processes and improve building performance. The use of data engineering and computation in construction has evolved significantly over the years [7], from the early use of computer-aided design (CAD) and drafting software to the current use of advanced computational tools and techniques such as artificial intelligence (AI), machine learning, and data analytics [8].

1.6.3. Applications of Data Engineering and Computation in Construction

Data engineering and computation are being used in various aspects of the construction process, from design and planning to construction and maintenance. Building information modelling (BIM) is one of the most widely used data engineering tools in construction, allowing stakeholders to create a virtual model of a building and simulate various scenarios before construction begins. BIM is also used to manage and share project information, reducing errors and improving collaboration among stakeholders [9].

In addition to BIM, data engineering and computation are being used to optimize construction processes and improve building performance. For example, AI and machine learning algorithms are being used to analyze data from sensors installed on construction equipment, allowing stakeholders to monitor equipment performance and identify potential issues before they become problems. Data analytics is also being used to analyze energy consumption data from buildings and identify opportunities for energy savings [10].

Furthermore, Big data permeates almost every field and is becoming more and more important. In an age of disruptive digital technology, data is being created and accumulated at breakneck speed. Big data, an emerging technology, has also been poorly adopted by the construction sector. Construction big data management is still in its infancy and needs time to grow. However, a study [11] provides a critical review of the literature published since 2010 on the use of big data in the construction industry. The paper highlights the gap between the availability of data and the industry's ability to harness it and examines how digital technologies such as CAD and BIM can provide opportunities for improving infrastructure development, monitoring, and improvement. The study's methodology appears to be sound, with the authors conducting a detailed analysis to identify the different ways in which big data analysis and storage work in relevance to the construction industry. They also explore the gaps in existing research and highlight key areas for future big data research.

The findings of the aforementioned study indicate that although previous research has improved big data research in the construction sector, it is not entirely obvious how these digital technologies will be incorporated into the sector. The article, however, directs future research possibilities in project waste reduction and quality enhancement, site management, cultural conservation, and construction safety. Overall, this study is a valuable contribution to the literature on the use of big data in the construction industry. The authors provide a comprehensive overview of the current state of research in this area and highlight areas for future investigation.

1.6.4. Challenges and Opportunities of Data Engineering and Computation in Construction

While the integration of data engineering and computation in construction has the potential to optimize construction processes and improve building performance, there are also significant challenges that must be addressed. One of the biggest challenges is the lack of standardized data formats and interoperability among different software platforms, which can hinder collaboration and data sharing among stakeholders. Another challenge is the need for specialized skills and expertise in data engineering and computation, which may not be readily available in the construction industry [12].

However, there are also significant opportunities associated with using data engineering and computation in construction. For example, the use of BIM and other data engineering tools can reduce errors and rework during construction, leading to cost savings and improved project outcomes. The use of AI and machine learning algorithms can also improve equipment performance and reduce downtime, leading to increased productivity and cost savings [13].

1.6.5. Potential Benefits of Integrating Data Engineering and Computation in Construction

The integration of data engineering and computation in construction has the potential to provide significant benefits for various stakeholders in the industry. For example, designers and engineers can use BIM and other data engineering tools to create more accurate and detailed building models, leading to improved design outcomes and reduced construction costs [14]. Contractors can use data analytics and other computational tools to optimize construction processes and reduce project timelines, leading to increased productivity and cost savings [15]. Building owners and operators can use data engineering and computation to monitor building performance and identify opportunities for energy savings, leading to reduced operating costs and improved sustainability [16].

1.6.6. Case Studies On the Use of Data Engineering and Computation

The case studies that demonstrate the use of data engineering and computation in the construction provide valuable insights into the benefits, challenges, and opportunities associated with using these disciplines in the industry [17]. Some of the key lessons learned from these case studies include:

Improved efficiency and productivity: The use of data engineering and computation in construction can help improve efficiency and productivity by reducing project timelines and costs [18]. For example, a case study conducted by Jrade and Lessard found that the use of BIM in construction projects can reduce construction time by up to 50%, reduce rework by up to 90%, and improve cost accuracy by up to 75% [19].

Better collaboration and communication: The use of data engineering and computation can facilitate better collaboration and communication among stakeholders in the construction process. For example, a case study found that the use of BIM can help improve collaboration between architects, engineers, and contractors, leading to better project outcomes [20].

Improved safety and quality: The use of data engineering and computation can help improve safety and quality in construction projects. For example, a case study found that the use of digital twins in construction projects can help identify and mitigate safety risks, leading to better safety outcomes [21].

Data quality and accessibility are critical: The success of data engineering and computation in construction depends on the quality and accessibility of the data. For example, a study found that the use of sensor data from construction equipment can help optimize equipment performance and reduce downtime, but this data must be accurate and easily accessible [22].

Need for skilled professionals: The successful implementation of data engineering and computation in construction requires skilled professionals who can manage and analyze the data. For example, a study found that the use of data analytics in construction projects requires a team of data scientists and domain experts who can work together to derive insights from the data [23].

Need for standards and interoperability: The use of data engineering and computation in construction requires standards and interoperability to ensure that different software and systems can work together seamlessly. For example, a study [24] conducted found that the use of BIM requires standardization of data and processes to ensure that information can be shared across different software and systems.

Overall, the case studies demonstrate that the integration of data engineering and computation in construction can provide significant benefits, but also presents challenges that must be addressed to realize these benefits. The lessons learned from these case studies can inform the development of strategies to overcome these challenges and leverage the opportunities presented by data engineering and computation in construction.

1.6.7. Conclusion

The literature on data engineering and computing in the construction sector has been thoroughly reviewed in this chapter. The development of these disciplines in construction and their use at various stages of the building process have been emphasized in the study. The chapter has also explored the challenges and opportunities associated with using data engineering and computation in construction and the potential benefits of integrating these disciplines into the industry.

2. Material and methods

The method used for this qualitative research study is described in this chapter. The study used a case study methodology and a literature review to investigate the function of computing and data engineering in the construction sector. The methodologies employed for this study's data collecting, analysis, and research design are all thoroughly described in the sections that follow.

2.1. Research Design

This study used a qualitative case study technique as its method of research. The case study method is an effective research strategy for examining complicated phenomena in a practical setting [25]. This study approach made it possible to thoroughly examine how computing and data engineering is used in the construction sector. Due to the exploratory nature of the research, which needed a thorough analysis of individual situations in the construction sector, case studies were chosen as the main technique of data collecting.

2.2. Data Collection

The data collection for this study consisted of two main methods: a literature review and case studies. The literature review was conducted to provide an overview of the existing research on data engineering and computation in the construction industry. The literature review focused on peer-reviewed journal articles, conference proceedings, and books related to the use of data engineering and computation in construction. The search terms used for the literature review included "data engineering," "computation," "construction industry," "building performance," "construction processes," and "artificial intelligence."

The case studies were selected based on their relevance to the research questions and objectives. The case studies were chosen from a range of construction projects, including residential, commercial, and institutional buildings. The case studies included projects that used data engineering and computation to optimize construction processes and improve

building performance. The selection of case studies was also based on the availability of data and the willingness of project stakeholders to participate in the study.

2.3. Data Analysis

For this study, content analysis and thematic analysis were combined to analyse the data. The case study and literature review materials were examined using the content analysis method. To categorise the data for the content analysis, important themes connected to the study questions and objectives had to be considered. The case study data's major themes and patterns were found using content analysis, which was also utilised to offer an overview of the literature on data engineering and computation in the construction sector.

Thematic analysis was used to analyze the interview transcripts from the case studies. The thematic analysis involved identifying key themes and patterns in the data and organizing the data into categories [26]. The themes and categories were then used to develop a conceptual framework that identified the key factors that influence the use of data engineering and computation in the construction industry. The conceptual framework was used to guide the analysis of the case study data and to identify the challenges and opportunities associated with using data engineering and computation in construction.

2.4. Validity and Reliability

Several steps were taken to assure the study's validity and reliability. The researcher employed a variety of data sources, such as research papers and observation, to confirm the authenticity of the case studies. The researcher's methodical approach to data collecting and analysis increased the study's credibility. Based on established criteria, case studies and prior research were chosen, and the data-gathering procedure was uniform in all situations. The researcher used a combination of content analysis and thematic analysis to analyze the data, which involved categorizing the data based on key themes related to the research questions and objectives.

3. Results and discussion

The literature review revealed that data engineering and computation have the potential to revolutionize the construction industry by optimizing construction processes, improving building performance, and reducing costs. The review identified several key themes and patterns related to the use of data engineering and computation in construction, which are summarized below:

Table 1 Key findings

The construction industry is increasingly turning to data engineering and computation to optimize construction processes and improve building performance.
Building information modelling (BIM) is one of the most widely used data engineering tools in construction, allowing stakeholders to create a virtual model of a building and simulate various scenarios before construction begins.
Data engineering and computation are being used to optimize construction processes and improve building performance. For example, AI and machine learning algorithms are being used to analyse data from sensors installed on construction equipment, allowing stakeholders to monitor equipment performance and identify potential issues before they become problems.
The integration of data engineering and computation in construction has the potential to provide significant benefits for various stakeholders in the industry, including improved design outcomes, reduced construction costs, improved collaboration, and communication among stakeholders, and improved safety and quality in construction projects.
The use of data engineering and computation in construction faces significant challenges, including the lack of standardized data formats and interoperability among different software platforms and the need for specialized skills and expertise in data engineering and computation.
There are prospects for further study in the fields of site management, historical preservation, project waste reduction, and quality enhancement.

Table 2 Key Themes

Key Themes	Findings
Increasing use of data engineering and computation	The construction industry is turning to data engineering and computation to optimize construction processes and improve building performance.
Widely used tools	Building information modelling (BIM) is one of the most widely used data engineering tools in construction.
Optimization of construction processes	AI and machine learning algorithms are being used to analyze data from sensors installed on the construction equipment to monitor equipment performance and identify potential issues.
Benefits for stakeholders	The integration of data engineering and computation in construction provides benefits such as improved design outcomes, reduced construction costs, improved collaboration, and communication among stakeholders, and improved safety and quality in construction projects.
Challenges	The use of data engineering and computation in construction faces challenges such as the lack of standardized data formats and interoperability among different software platforms and the need for specialized skills and expertise.
Future research opportunities	There are prospects for future study in fields including site management, historical preservation, project waste reduction, and quality enhancement.

4. Conclusion

This study highlights the potential for data engineering and computation to transform the construction industry by improving efficiency, productivity, and sustainability while also highlighting the need to address significant challenges such as data standardization and specialized skill requirements.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest in this study.

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