Clash Detection in Construction Project by BIM

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Abstract

Clash detection utilizing Building Information Modeling (BIM) has changed construction project management by increasing design precision and reducing costs, and in accelerating project timelines. In this review, a novel integration of BIM with machine learning (ML) and artificial intelligence (AI) techniques for automating and improving clash detection processes is explored. The study categorizes conflicts as hard, soft and workflow clashes, and highlights the importance of BIM tool Revit and Navisworks in resolving interdisciplinary conflicts across architectural, structural and MEP systems.

In this paper, we identify three key challenges that impede automation—data quality, class imbalance, and incomplete datasets. It uniquely identifies synthetic data generation and advanced algorithms as pathways to fill these gaps. The review provides a framework for improving construction efficiency through the integration of emerging AI technologies within BIM workflows, and within that, presents a way of minimizing risks and increasing automation on the construction site. Not only does this work help bridge existing research gaps, it also provides actionable insights for modernizing construction practices that have a roadmap for the future of clash detection.

Keywords: Building Information Modeling (BIM), Clash Detection, Construction Project Management, Multidisciplinary Collaboration, Machine Learning in BIM, Hard and Soft Clashes, Revit, Navisworks, Cost and Time Efficiency

INTRODUCTION

The construction industry is undergoing a revolution with the advent of Building Information Modeling (BIM) – which has revolutionized construction by creating a more collaborative and efficient environment where designs, construction and projects happen. For one of the key innovations within BIM, its ability to identify and resolve clashes—conflicts in between various building systems (architectural, structural, MEP). Key in the prevention of costly errors and delays is clash detection which has been revolutionised with the adoption of BIM. The process is typically categorized into three types: physical conflicts between components (hard clashes), violations of space or regulatory requirement (soft clashes) or sequencing or scheduling problems (workflow clashes).

In the past, clash detection was a time and labour-intensive process but integrated BIM tools such as Autodesk Revit and Navisworks automate much of the process, increasing efficiency and reducing human error. Additionally, the development of techniques in the field of machine learning and artificial neural networks have integrally brought the opportunity for fully autonomous clash detection and resolution leading to quicker and more precise results. However, much has been accomplished on the technological front in terms of data quality, class imbalance, and complete datasets for predictive models.

In this review, we discuss current state of the art of BIM based clash detection, including methodologies, tools, and the use of machine learning to automate processes. It presents the revolutionary effect of BIM on construction management and points out how multidisciplinary coordination and early conflict resolution will help to minimize errors, costs and delays. The paper also fills these gaps, and proposes future research area.

RESEARCH SIGNIFICANCE

The research paper highlights the major role played by Technology of Building Information Modeling (BIM) in tackling and managing clashes in construction projects. The significance of this study can be highlighted as follows:

1) Enhanced Understanding of Clash Types:
   Research categorizes clashes into hard, soft, and workflow types to establish a basis for locating and correcting conflict in multidisciplinary construction projects. The way it is classified helps understand the nature and causes of clashes by providing more accurate means of detection and resolution.
2) Advancing Clash Detection Through Automation and Machine Learning:
   Potential of machine learning algorithms to automate clash detection and resolution processes is explored in the study. It also demonstrates the use of cutting edge methods like multilabel synthetic oversampling (MSOS) to address data quality issues and how artificial intelligence can give new life to old workflows and increase efficiency.
3) Collaborative Coordination Across Disciplines:
   The research highlights the need for collaboration in BIM based clash detection, real time information sharing, interdisciplinary coordination and effective

communication among stakeholders. It allows proactive conflict resolution and lowers errors and increases cohesion of the project.

4) Economic and Temporal Benefits:
Through BIM based clash detection, case studies and comparative analyses show large cost and time savings. For instance, the research shows that reduction in rework, better scheduling or construction safety for kinds of projects including healthcare or public infrastructure benefits.
5) Holistic Adoption of BIM Tools and Techniques:
The paper illustrates how advanced BIM technologies such as Autodesk Revit and Navisworks Manage help in improving construction planning, with less errors. Using high Levels of Development (LOD) facilitates more accurate models which improve chances of reliability for clash detection, and aid in better project deliverables.
6) Development of Future Directions:
Emerging technologies, such as artificial intelligence, augmented reality, blockchain, and generative design, are shown to be potential BIM based clash detection innovations in the study. The goal is to help make construction workflows more integrated and efficient.
7) Impact on Industry Practices:
The contribution of these findings elucidates how the use of BIM significantly improves when it comes to reducing spatial conflicts in projects that are highly complicated, to optimizing resource allocation and decision making. It underscores the rising imperative for BIM adoption across the breadth of project typologies, including healthcare, infrastructure and commercial.

This research contributes to the wider field of construction project management by addressing existing challenges and proposing advanced methodologies to enable the use of BIM to maximize efficiency, productivity and cost effectiveness in construction while serving as a roadmap.

LITERATURE REVIEW

1. Types of Clashes In BIM

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011), addresses types of clashes in BIM (hard, soft, and workflow clashes) The book addresses the issue of conflicts in building projects. The basic concept of a clash, its beginnings, a brief history, and its evolution in the built environment and construction management utilizing Building Information Modeling (BIM) are all covered in the first section. The paper's second section is devoted to a thorough classification of conflicts. Every category is determined by the unique traits and detection methods of that category. Hard collisions are only oriented geometrically.

The paper of **Singh, Gu, and Wang et al (2011)** clarifies the central BIM role in addressing clashes of diverse types that can arise in multi-disciplinary construction projects. The study categorizes clashes into three primary types: hard, soft, and workflow clashes. Hard Clashes are clashes in which physical items (pipes and beams, for example) are present at the same location, causing constructability problems. The simplest to detect with BIM tools are these clashes. Soft clashes refer to non-physical conflicts, where the components do not need to collide, but do not satisfy design or regulatory requirements such as not enough space for maintenance access. Process based conflicts resulting from misaligned schedules, incorrect data input, or errors in construction planning sequencing are referred to as workflow clashes. The authors posit that to resolve these clashes, not only are detection tools necessary, but also an integrated platform for real time collaboration and decision making. Using BIM to address these clash types and types in a comprehensive manner boost efficiency and saves cost on project rework.

2. Automation and Algorithms in Clash Detection

Geyer, P. et al (2010) studied on key developments and challenges in the use of Building Information Modeling (BIM) tools to detect and solve clashes. Since Navisworks has been widely adopted, the resolution of clashes is still a process performed manually and essentially requires a new way of doing things. Studies generate machine learning (ML) as a promising solution: its potential to automate the clash resolution and boost efficiency. But development of effective ML models, including data preparing and algorithm selection, has been underexplored.

The details of creating successful ML models are explored in detail, and as such these are identified as a significant research gap. Some of them are: dealing with unbalanced classes and restricted availability of data; both are supposed to affect the model's performance. To address large class imbalance problem, the study introduces a multilabel synthetic oversampling (MSOS) method to create synthetic data which helps mitigate poor data quality by generating synthetic data. Specifically, five machine learning algorithms are evaluated as predictors of resolved clash options and artificial neural networks are found to have the highest accuracy of approximately 80%. The results again reinforce the need for a robust dataset augmented with synthetic data as input to train effective ML models. Overall, the review points to the large potential that machine learning has in changing the way clash resolution is conducted while recognizing critical challenges that need to be better understood.

3. Collaborative Clash Detection and Coordination

Azhar, S. et al (2012), model coordination in complex construction projects is demonstrated as a crucial factor to reduce clash related risk. Although the clash detection process is automated, the consequent reviewing and resolution will require better methods. However, previous research performed machine learning and data mining applications to identify MEP system clashes, but had limited and noncomprehensive dataset for all major disciplines covered in an organization. There is still quite a large gap to be bridged to identify specific clash attribute combinations important for accurate relevance prediction.

In addressing these limitations, this study applies an Artificial Neural Network multilayer perceptron algorithm to a wider dataset, attaining over 80% precision in clash relevance prediction. The research contributes advancements to construction project management and BIM applications by identifying key BIM object attribute(s). It suggests holistic approaches that include all disciplines to make valuable contributions to improve the resolution of clash and making decisions in construction.

4. BIM Tools and Software for Clash Detection

The modeling is carried out in Revit and clash detection in Navisworks Manage. BIM tools that use these tools effectively identify conflicts be- tween structural, architectural or plumbing systems and increase the construction planning and reduce the costs by identifying the issues early in the design process. **Kim, J., et al (2012).,** studied the Clash detection's impact on construction planning for apartment projects in Jakarta is discussed. The importance of the Building Information Modeling (BIM) methodology in identifying conflicts among the structural, architectural, and MEP systems, and reducing resulting costly errors that commonly occur with traditional methods of design, construction, and operation platforms are discussed. The modeling part of the study is done in Revit and the clash analysis part by Navisworks Manage for the conflicts between the 6th floor to the roof starting from the 1st floor which is used as an example for the 24th floor. Out of an aggregate total of 121 conflict points, 95 appeared on the 24th floor, mostly in the architectural, structural, and plumbing systems. The study shows that construction cost can be reduced through the application of the collision detection techniques, resulting savings above 30 million rupiah. This research demonstrates the potential for integrating advanced BIM technology to enhance construction efficiency, reduce conflicts and minimize costs, a model for modern construction practice.

Clash Detection Key BIM Tools Autodesk Revit: It is used for 3D modeling to produce detailed building design which can be analyzed for potential conflicts. Autodesk Navisworks: Clash Detective feature of this software is critical for detecting clashes between the architectural, structural and MEP systems.

5. Impact of Clash Detection on Project Cost and Time Efficiency

Zhang, J., Teizer, J. et al (2013) Case Studies aims to show the clash detection process in BIM and matches with a number of key themes in already existing literature. By focusing on the role of BIM in enhancing information management and coordination, the paper exemplifies the benefits of BIM in reducing errors and improving design efficiency, the very benefits of BIM generally.

Prior studies, which have shown that clash detection is a critical BIM function that mitigates risks, delays and saves cost by identifying conflicts early in the construction, is highlighted as an intensive BIM function. The paper adds value to the wider discussion on the variety of approaches to the clash detection from the technical perspective and in terms of addressing process accuracy and project needs, revealing the emphasis of the literature on methodology development. Using three case studies, the paper shows the practical use of BIM and clash detection and shows real world challenges and outcomes. We also discuss variability in clash detection results, due to model complexity, and parameter uncertainty, as in previous research. In conclusion, the paper locates the work in the literature on BIM, discussing pertinent methodologies, applications and challenges with clash detection.

Case Studies

- **Healthcare Facility Project**: Li et al. (2013) reported saving approximately \$1.2 million; a 40% reduction in rework, as a result of BIM based clash detection in a 300-bed hospital.
- **Infrastructure Project**: Success of BIM application in a metro rail project was documented by Memon et al. (2014) where clash detection prevented scheduling delays and improved construction safety.
- **Staub-French, S., & Fischer, M. (2001).** Employing 3D CAD is expected to reduce clash detection costs and schedules in airport construction projects, which is what this study set out to investigate and document.
- **Khemlani, L. (2007).** Public infrastructure is analyzed using BIM technologies, with the increased possibility for providing better clash detection and achieving significant time reduction identified as a focus of comparison.
- **Hardin, B. (2009).** It provided practical insights to the use of BIM for industrial facility projects in the area of cost reduction through clash detection.
- **Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011).** To this end, this foundational text detailed BIM applications in the infrastructure projects and gave significant improvements in clash detection speed and collaboration.
- **Azhar, S., Khalfan, M., & Maqsood, T. (2011).** BIM application in residential and healthcare projects were discussed, tackling cost and time efficiency gains.
- **Wu, W., & Issa, R. R. A. (2012).** BIM was shown in this study to be effective for solving conflicts in the spatial organization of healthcare facilities from the perspective of both operational and cost efficiency.
- **Khosrowshahi, F., & Arayici, Y. (2012).** Based on the discussion over BIM in improving clash detection in mixed use developments, a roadmap for adoption was presented.
- **Barlish, K., & Sullivan, K. (2012).** BIM benefits were evaluated in office building projects based on the cost and time savings, from the clash detection.
- **Jin, R., Hancock, C., Tang, L., Hong, J., & Shang, H. (2018).** This project has evaluated the efficaciness of BIM in the commercial construction with the potential to detect and resolve clashes during the design stages.
- **El-Nimr, R., Farghaly, K., & Abdel-Rahman, H. (2019).** BIM applied to high rise buildings was explored and its application in detecting and mitigating spatial conflicts was highlighted.

Comparative study Report

By doing a comparison analysis, we determine the true time and cost savings utilizing the Clash Detection approach.

Table 2: Summary of Cost, Time, and Detection Efficiency

Study	Project Type	Cost Savings (%)	Time Savings (%)	Clash Detection Efficiency (%)	Number of Clashes Detected
Staub-French & Fischer (2001)	Airport Projects	6.5	9	90	450
Khemlani (2007)	Public Infrastructure	6.5	20	95	800
Hardin (2009)	Industrial Facilities	7	6	93	600
Eastman et al. (2011)	Infrastructure	9	7	95	700
Azhar et al. (2011)	Residential, Healthcare	10	7	90	500
Wu & Issa (2012)	Healthcare	9	10.5	88	550
Khosrowshahi & Arayici (2012)	Mixed-use Development	8.5	7	92	600
Barlish & Sullivan (2012)	Office Building	10	9	87	400
Jin et al. (2018)	Commercial Building	7.5	8.5	85	300
El-Nimr et al. (2019)	High-rise Building	6	7	85	400

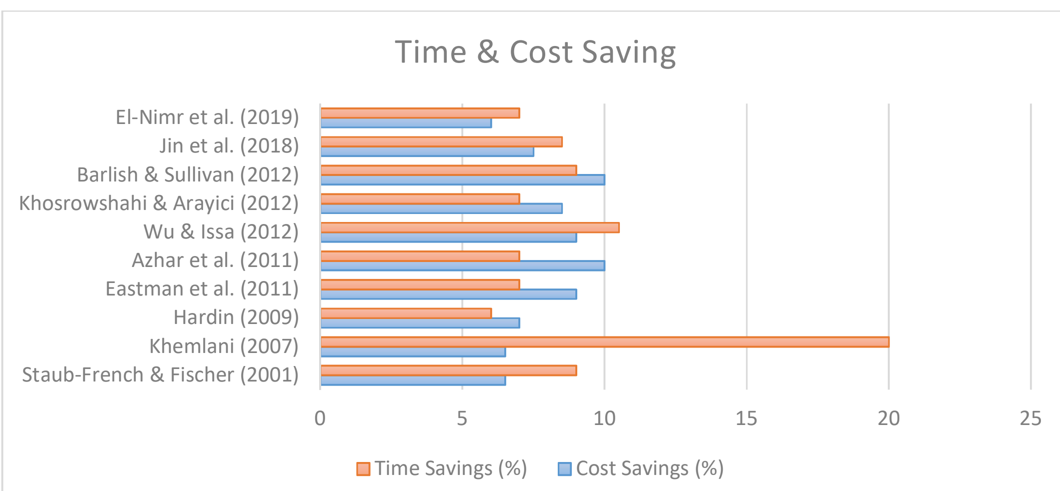

Fig.7: - Cost & Time saving (%) from Clash Detection by BIM

Discussion

a) **Simultaneous Design of Architecture and MEP Plans:** *WALL-BASED SYSTEM:* **-** The concurrent design of **architectural and MEP systems**, with MEP designs adhering to a **wall-based approach**, was one of the main conclusions of this study. Because MEP systems are often reliant on architectural layouts, particularly with regard to space allocation and placement within walls and ceilings, this approach is essential.

b) **Time and Collaboration:** *Critical Factors in BIM for Clash Detection:* **-** Two essential components of Building Information Modeling (BIM) for increasing the efficacy and efficiency of collision detection are *time and collaboration*. BIM is more than simply a 3D modeling tool; it connects people, actions time (4D), and cooperation across numerous teams, breaking down the boundaries between the real and virtual worlds and enabling early conflict detection and resolution when it counts most: in the early stages of a project. Complementing one another, these two elements help to improve project coordination, reduce construction errors, and streamline operations. Here, we examine how BIM-based clash detection is impacted by *time and collaboration.*

1. **Time in BIM: The Fourth Dimension (4D BIM)**

- Preemptive Clash Detection
- Scheduling Coordination
- Reduced Delays and Rework

2. **Collaboration in BIM: Enhancing Coordination Among Stakeholders**

- Real-Time Information Sharing
- Interdisciplinary Coordination
- Effective Communication and Problem Resolution
- Clash Resolution Meetings

3. **The Combined Impact of Time and Collaboration on Clash Detection**

- Time Integration: It gives the project team the ability to resolve conflicts not just with regard to spatial linkages but also with regard to the timing of those conflicts within the building schedule.
- Collaboration: With the help of contractors, engineers, architects, and other stakeholders, it guarantees that all team members can collaborate to find timely and workable solutions to conflicts.

c) Level of Development (LOD) in BIM

The LOD system is categorized into distinct levels:

- **LOD 100:** Conceptual design.
- **LOD 200:** Preliminary design.
- **LOD 300:** Precise models for clash detection.
- **LOD 350:** Models with connections between elements.
- **LOD 400:** Detailed construction-ready models.
- **LOD 500:** Models representing as-built conditions.

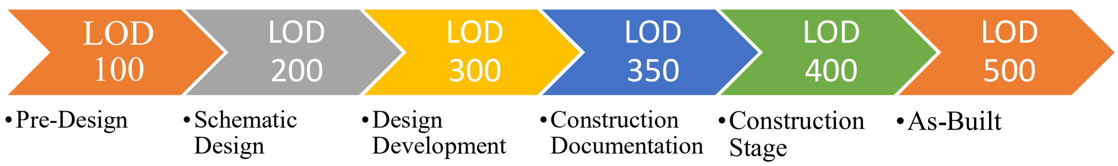

Fig.8: - Development of LOD

As the project progresses into higher LOD stages, the model's reliability increases. **LOD 300** introduces precise measurements and material details, enabling meaningful clash detection between systems such as walls, ducts, beams, and piping. By **LOD 350**, the model incorporates **connections between elements** like joints or brackets, which further refines the clash detection process, allowing teams to anticipate and resolve issues that arise due to connections between building elements.

The **Level of Development (LOD)** plays a critical role in the accuracy of clash detection. As the model progresses from conceptual design (LOD 100) to more detailed levels (LOD 300 and beyond), the ability to detect and resolve clashes increases significantly. Higher LOD levels lead to more **reliable models**, which are crucial for preventing costly construction-phase issues.

d) 10-D BIM System: Beyond Clash Detection

The investigation of **BIM's potential to function up to a 10D system** was another important component of the study. Although the majority of projects usually use **3D to 6D BIM**, [7] which includes dimensions like time (4D), cost (5D), and sustainability (6D), BIM can be extended to include other dimensions as well:

- **7D:** Facility management.
- **8D:** Safety planning.
- **9D:** Lean construction.
- **10D:** Industrialized construction processes.

e) BIM Execution Plan (BEP)

A **BIM Execution Plan (BEP)** is a foundational tool to ensure clear and repeated procedures are defined and followed in **clash detection** throughout the project.[4] The importance of formalizing roles, data management and resolution processes for maintaining the **project's efficiency** and keep clash detection as proactive process instead of reactive.

- **Roles and Responsibilities:** It ensures that everyone knows what role to play during clash detection and resolution.
- **Data Exchange Protocols:** Sits as a standard for how various BIM data transfer between different platforms and teams across the enterprise.
- **Clash Detection Procedures:** Changes the format of the clash detection, defines the software to be used (e.g. Navisworks) as well as how to document and resolve the clashes.

f) Future Directions

Emerging technologies and methodologies promise to enhance BIM-based clash detection:

1. **Artificial Intelligence (AI) and Machine Learning**: Automating clash identification and resolution processes.
2. **Generative Design**: Designing models that are inherently clash-free.
3. **Augmented Reality (AR) and Virtual Reality (VR)**: Providing immersive visualization for stakeholders.
4. **Blockchain Technology**: Ensuring secure and transparent collaboration in BIM workflows.

CONCLUSION

Extensively, this review paper examines the contribution of Building Information Modeling (BIM) to improve the clash detection and resolution in building projects of various types. The findings and insights can be summarized as follows:

1. BIM's Key Contributions to Clash Detection

- Categorization of Clashes:

  Systematic identification of hard, soft, and workflow clashes is achieved by BIM in order to address conflicts in spatial geometry, regulatory requirements as well as process workflow conflicts in an improved manner.

- Improved Detection Efficiency:

  Advanced BIM tools, like Autodesk Revit, and Navisworks Manage improve the accuracy and the efficiency with which we find the conflicts between architectural, structural, and MEP systems, that are reducing errors in the design phase.

2. Economic and Temporal Benefits.

- Cost Reduction:

  Using multiple case studies, it is shown that BIM significantly lowers rework and associated costs (with savings of 6 to 10% across healthcare, infrastructure, and residential building types).

- Time Savings:

  Clash detection by way of BIM yields return in 1 to 2 years that spans 7 to 20 % of project duration, depending on scope and complexity.

3. Collaborative Benefits

- Enhanced Communication:

  Information sharing in real time and the increase in interdisciplinarity provide real opportunities for improved coordination of architects, engineers, and contractors so as to minimize miscommunication and facilitate effective decision making.

- Proactive Conflict Resolution:

  Stakeholders are encouraged to address issues before they become problems, at an early stage of the project lifecycle to the benefit of projects users with clash resolution meetings and integrated BIM workflows.

4. Role of Emerging Technologies

- Artificial Intelligence and Machine Learning:

  Results of automation of clash detection using AI-based and machine learning algorithms are promising suggesting methods such as multilabel synthetic oversampling (MSOS) to improve both data quality and resolution accuracy.

- Augmented Reality (AR) and Virtual Reality (VR):

  These tools facilitate immersive visualizations of spatial conflict for better stakeholder understanding, and more effective clash resolution.

- Blockchain Technology:

  As a secure platform for collaboration, blockchain emerges to be a great platform to exchange transparent data and improve accountability of BIM workflows.

5. Importance of the Higher Levels of Development (LOD)

Most LOD stages, but particularly those above the LOD 300 mark, greatly improve clash detection accuracy through the provision of accurate, reliable models accuracy by providing detailed and reliable models. Thanks to these refined models, specific conflict detection is precise, even in complex interactions, such as the joints and connections.

6. Future Prospects

- Generative Design:

  Generative design applied to future BIM systems might obviate the use of manual conflict detection, with inherently clash-free models becoming possible.

- 10D BIM:

  BIM moves beyond traditional 3D + 4D (time) to 6D (facility management), 7D (safety planning), 8D (lean construction), and 9D (industrialized processes), each of which further increases the value added to BIM.

7. Challenges and Opportunities

- Data Quality and Availability:

  Creating robust datasets, and dealing with things such as data imbalance, for improving machine learning based clash detection models, are the other two critical aspects.

- Integration Across Disciplines:

  To ensure that architectural, structural and MEP systems are coordinated, it is necessary to use comprehensive and holistic approach.

Final Remarks

Modern construction has definitely been benefited by BIM greatly, as it is significantly better in match detect, cost cut, and time effectiveness. BIM appears to provide a proactive and integrated approach to conflict resolution in that it generates partnership between stakeholders, utilises new technologies and delivers higher levels of management discipline. More research and progress will be made in BIM methodologies to increase its impact, speeding the construction industry to greater efficiency, sustainability and precision.

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Data Availability Statement

The data supporting the findings of this study are derived from publicly available literature and case studies cited throughout the paper. Specific references, datasets, and tools used in the research are documented and referenced accordingly in the text. No new experimental datasets were generated for this review. Any additional information or data inquiries can be addressed by contacting the corresponding author or accessing the respective publications referenced in this paper.